Tactical Satellite Orbital Simulation and Requirements Study

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RAND

PREFACE

This Note documents the results of a preliminary analysis of space communications requirements that employs scenarios for military operations in three widely separated geographical areas in which U.S. contingency operations could occur.

The objectives of this research are to:

- Assess communications requirements that were not met by military resources for Desert Shield/Desert Storm and other recent operations and might not be met without additional military resources in potential future contingencies, including a hypothetical contingency in the southern hemisphere.
- Determine how military satellites could be used to overcome shortfalls between requirements and existing or planned military communication systems.

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SUMMARY

Operations Just Cause and Desert Shield/Storm provided valuable operational experience regarding tactical communications in contingency operations. This Note analyzes these operations, particularly Desert Shield/Storm, to determine the extent to which the communication requirements were met by MILSATCOM and commercial communication satellite systems. It is concluded that service was adequate in most respects but that this outcome may have been a consequence of two fortuitous circumstances. First, Operation Just Cause benefited from a well-developed U.S. military communication infrastructure, whereas Operation Desert Shield/Storm benefited from having an extended period in which to establish such an infrastructure. Second, neither operation experienced enemy jamming. The properties of commercial communication satellite systems and most fielded military earth terminals are such that significant degradation can be expected in the face of determined jamming.

To help assess the way in which improved military terminals coupled with lightsats or smallsats could be used to overcome communication shortfalls in future contingency operations, RAND developed three hypothetical scenarios to be tested in a suitable computer simulation. These scenarios, which are set in Southwest Asia (similar to Desert Shield/Storm), Korea, and South America, portray contingency operations up to corps level with significant jamming capability attributed to the enemy. A methodology for incorporating communication requirements and equipment databases and performing an iterative gaming process to develop and assess alternative communication structures is described.

Future research should be directed toward (1) improving the requirements and equipment databases, and (2) developing the comprehensive computer simulation required to test the operational scenarios under realistic circumstances. This will involve the development of a sophisticated system configuration tool, the basis for which is presented.

ACKNOWLEDGMENTS

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ACRONYMS

AASLT	Air Assault
ABN	Airborne Battalion
ACP	Assault Command Post
ACPC	Arroyo Center Policy Committee
ADA	Air Defense Artillery
AFCC	Air Force Communications Command
AFSAT	Air Force Satellite Transponder
AFSOUTH	Air Force Southern Command
AFSPACECOM	Air Force Space Command
AJ	Anti-Jam
AN	Analysis Division of USSPACECOM
ANIK	Canadian Domestic Satellite
AOR	Area of Responsibility
APC	Armored Personnel Carrier
ARCENT	Army Central Command
ARCONET	Atlantic Richfield Corporation Network
ASTRO	SIMAN module for astrodynamic environment
AUSSAT	Australian Domestic Satellite
AUTOVON	Automatic Voice Network
AVN	Aviation
BB	Battleship
BBBG	Battleship Battle Group
BDE	Brigade
BF	
C^2	Command and Control
C^3	Command, Control, and Communications
C-BAND	Frequency Band Between 4 GHz and 8 GHz
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CARS	Computer-Assisted Requisition System
CECOM	Communications/Electronics Command
CENTAF	Central Command, Air Force Component
CENTCOM	Central Command
CGA	Color Graphics Adapter
CINC	Commander in Chief
CINCSOUTH	Commander in Chief, Southern Command
COMNET	Commercial Network Exploration Tool
COMSTAR	U.S. Domestic Telephone Communications Satellite
COMSAT	Communications Satellite Corporation
CONUS	Continental United States
COSCOM	Corps Support Command
CSI	Commercial SATCOM Interconnectivity
CV	Carrier
CVBG	Carrier Battle Group
DABBS	DISA Acquisition Bulletin Board System
DARPA	Defense Advanced Research Projects Agency
dB	Decibels
dB/Hz	Decibels per Hertz

dBI	Decibels Relative to Isotropic Gain
dB/K	Decibels per Degrees Kelvin
dBHz/m²	Decibels Hertz per Meters Squared
DBMS	Data Base Management System
dBW	Decibels Watts
dBW/K-Hz	Decibels per Degrees Kelvin per Hertz
dBW/m²	Decibels Watts per Meters Squared
DCA	Defense Communications Agency
DCS	Defense Communications System
DECCO	Defense Commercial Communications Office
DISA	Defense Information System Agency
DMA	Defense Mapping Agency
DMZ	Demilitarized Zone
DOMSAT	Domestic Communication Satellite
DS-1	Data Signal Format: 1.544 Mb/s (also T1)
DSCS	Defense Satellite Communications System
DTG	Digital Transmission Group
E_b/N_0	Energy per Bit per Single-Sided Noise Spectral Density
EHF	Extremely High Frequency
EIRP	Equivalent Isotropic Radiated Power
EL	East Atlantic DSCS Satellite
FAA/NWS	Federal Aviation Agency/National Weather Service
FCC	Federal Communications Commission
FFRDC	Federally Funded Research and Development Center
FLTSATCOM	Fleet Satellite Communications
FSSG	Force Service Support Group
GAPFILLER	Navy Satellite Launched Between FLTSAT and LEASAT
GEO	Geostationary Orbit
GHz	GigaHertz
GMF	Ground Mobile Forces
GSTAR	U.S. Commercial Communications Satellite
G/T	Gain-to-Temperature Ratio
IBS	International Business Service
IDCSP	Initial Defense Communication Satellite Program
IDSCS	Initial Defense Satellite Communication System
IF	Intermediate Frequency
INMARSAT	International Maritime Satellite Organization
INTELSAT	International Telecommunications Satellite Organization
IO	Indian Ocean DSCS Satellite
ISDB	Integrated SATCOM Data Base
IQO	Inquiry Quote Order
J6	Command, Control, Communications, and Computer Systems, Joint Chiefs of Staff
J6Z	Contingency Support Division, Joint Chiefs of Staff
JCS	Joint Chiefs of Staff
JTF	Joint Task Force
JTFME	Joint Task Force Middle East
JTFSA	Joint Task Force Saudi Arabia
kb/s	Kilobits per Second (also kbps)
KKMC	King Khalid Military City
K_u-BAND	Frequency Band Between 12 GHz and 18 GHz
LEASAT	Leased Satellite (Navy)

L-BAND	Frequency Band Between 1 GHz and 2 GHz
LES-9	Experimental military communication satellite
LIGHTSAT	Small, Tactically Oriented Satellite
LOG	Logistics Command
LPI	Low Probability of Intercept
LTASS	Lightweight Tactical Army SATCOM System
MACSAT	Experimental DARPA Lightsat
MARCENT	Marine Central Command
MARSOUTH	Marine Southern Command
Mb/s	Megabits per Second (also Mbps)
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
MHz	MegaHertz
MILSATCOM	Military Satellite Communications
MILSTAR	Military Strategic and Tactical Relay
MMDB	MILSTAR Master Data Base
MODEM	Signal Modulator and Demodulator
MRDB	MILSATCOM Requirements Data Base
MSE	Mobile Subscriber Equipment
MTOE	Modified Table of Organization and Equipment
NAM	Network Assessment Model
NAVCENT	Navy Central Command
NAVSOUTH	Navy Southern Command
NCS	National Communications System
NS/EP	National Security/Emergency Preparedness
ODS/S	Operation Desert Shield/Storm
OJC	Operation Just Cause
OMEGA	Object-oriented Methodology and Environment for Graphic Analysis
OPLAN	Operations Plan
PTT	Post, Telegraph, and Telephone
RDES	Rapid Deployment Transportable Earth Stations
RF	Radio Frequency
RFP	Request for Proposal
ROK	Republic of Korea
RPCI	Office Symbol for the International Communications Service Branch of DECCO
RSSC	Regional Space Support Centers
SATCOM	Satellite Communications
SCRCDB	Satellite Communications Requirements and Capabilities Data Base
SHF	Super High Frequency
SIGSIM	Signature Simulator
SIMAN	System for Interactive Multispectral Analysis
SKW	SKW Corporation
SKYNET	British military communication satellite system
SOCCENT	Special Operations Command, Central
SOCOM	Special Operations Command
SOCSOUTH	Special Operations Command, Southern
SOI/MPA	Space Object Identification/Mission Payload Assessment
SOUTHCOM	Southern Command
SPT	Support

STIX	Commercial satellite communication interconnectivity, low-cost earth terminal
STS	STS, Inc., a subsidiary of California Microwave
SWA	Southwest Asia
T1	Data Signal Format: 1.544 Mb/s (also DS-1)
T3	Data Signal Format: 44.736 Mb/s
TACSAT	Tactical Satellite
TCO	Telecommunications Contracting Office
TFW	Tactical Fighter Wing
TMSO	Telecommunications Management and Services Office
TOE	Table of Organization and Equipment
TOSARS	Tactical Satellite Orbital Simulation and Requirements Study
TRADOC	Training and Doctrine Command
TSO	Telecommunications Service Order
TSP	Telecommunications Service Priority
TSR	Telecommunications Service Request
UHF	Ultra High Frequency
URDB	User Requirements Data Base
USARCO	U.S. Army Contracting Office
USARSPACECOM	United States Army Space Command
USCINCCENT	United States Commander in Chief, Central Command
USSPACECOM	United States Space Command
VSAT	Very Small Aperture Terminal
WATS	Wide Area Telephone Service
WP	Western Pacific DSCS
X-BAND	Frequency Band Between 8 GHz and 12 GHz

1. INTRODUCTION

Less than a century has passed since Marconi's first transatlantic radio telegraph transmission in 1901. From that start, radio communication has grown at a phenomenal and accelerating pace that shows no signs of diminishing. Although the principal applications of radio have been commercial, there has been a parallel military development. The role of radio, which was nascent during World War I, grew to major proportions in World War II, when it clearly demonstrated the importance of reliable communication for the command and control of modern warfare's armed forces.

The introduction of communication via earth satellites brought a new dimension to the utility of radio. Only a third of a century ago, the U.S. Navy used the earth's natural satellite, the moon, to establish low-data-rate communication between Washington, D.C., and Hawaii. This was followed by a large number of experiments and early communication systems involving both active and passive man-made earth satellites. Both military and commercial satellites have had reliable, high-capacity designs that have, with few exceptions, been placed in geostationary earth orbits. The commercial systems tend to be grouped into those, such as INTELSAT and INMARSAT, that are owned and operated by international organizations and those, such as COMSTAR, GSTAR, ANIK, and AUSSAT, that are owned and operated privately or cooperatively by governments in the region served. The military systems include MILSATCOM for the United States, SKYNET for the British, and the NATO system.

The first significant use of satellite communications in military operations was during the Vietnam war when the Initial Defense Communication Satellite Program (IDCSP) was used to establish a medium-data-rate link between Southeast Asia and Hawaii and, thence, to Washington, D.C. Later renamed the IDSCS, to designate it as a system rather than a program, it consisted of 26 simple, super high frequency (SHF) repeaters in randomly drifting satellites launched into equatorial, near-synchronous orbits between 1966 and 1968. Although not used in-theater for tactical communication, the IDSCS demonstrated the value of command and control by distant commanders using remote, near-real-time imagery.

The Grenada operation, Urgent Fury, used Fleet Satellite Communications (FLTSATCOM) for ultra high frequency (UHF) tactical communication in 1983. More recently, the larger Panama operation, Just Cause, made extensive use in 1989 of both FLTSATCOM at UHF and Defense Satellite Communications System (DSCS) at SHF for strategic as well as tactical communication. The great innovation during Just Cause was the

planned use of commercial satellite communication service through ALASCOM. The intent, however, was to support civil needs, not military ones.

Operation Desert Shield/Storm (ODS/S) put an entirely new dimension on the use of both military and commercial satellite communication service in a major conflict. High data rates were supported by MILSATCOM, using DSCS and FLTSATCOM, with support from the British SKYNET. Similar high data rates were also supported by the commercial systems, INTELSAT and INMARSAT. The total level of communication support was unprecedented and certainly, because of its demonstrated value, a harbinger of what will be expected and must be delivered in the future.

Yet, for all the success of satellite communication support in ODS/S, there is concern that what happened was not what would or could have happened had circumstances been less favorable. Despite having the fourth largest army in the world, the Iraqis were outclassed in many respects. Their lack of an adequate air defense led to an early near-total disruption of their command and control communications. At the same time, there was virtually no disruption of U.S. forces. Neither air nor missile attacks were directed at our major communication centers and no attempts were made to jam our military or commercial communication satellites. In fact, the only significant interference was self-interference.

Enemy interference aside, there is also the question whether communication needs were adequately satisfied. This is difficult, and perhaps impossible, to determine because of a number of factors. The operators of DSCS claim they provided all of the requested communication service and had capacity to spare. However, undocumented complaints of unfulfilled requirements have been heard. That these may have been the result of ignorance or of using improper procedures gives little comfort to frustrated communicators. Also, there were many problems relating to the interoperability of some equipment. With respect to the use of commercial satellite communication service, there undoubtedly was inefficient procurement in some cases and inefficient use in others. The difficulties posed by these and similar problems might have been greatly magnified had there not been the luxury of an undisturbed six-month period in which to bring in troops and equipment and to establish a communication network.

A future operation conducted under more adverse circumstances than ODS/S might experience much greater difficulty. For that reason, it is prudent to investigate the ability of MILSATCOM, with suitable commercial satellite communication augmentation, to support better-resisted future operations. The result will be better statements of need, operational procedures, equipment modification, and possibly, MILSATCOM augmentation. The research reported herein addresses some of these issues.

The objectives of the research were to:

- Assess communications requirements that were not met by military resources for Desert Shield/Storm and other recent operations and might not be met without additional military resources in potential future contingencies, including a hypothetical contingency in the southern hemisphere.
- Determine how tactical satellites could be used to overcome shortfalls between requirements and existing or planned military communication systems.

The RAND effort was to be one element of a three-element program, each with its own independent deliverable. The two other elements were to be performed through USSPACECOM. SKW Corporation was to collect military communications requirements for Desert Shield/Storm and compile a communications database. TEXTRON was to develop a communications network simulator with the time-varying characteristics of satellites. The TEXTRON effort was terminated early in the project.

RAND's responsibilities extended over all three elements oi the program. They included:

- Developing communication requirements data collection plans.
- Contributing information, experience, and lessons learned from related space system and Army communication activities at RAND.
- Formulating southern hemisphere scenarios in sufficient detail for the desired tactical satellite utility analysis.
- Performing analyses to develop tactical communication satellite constellations for Desert Shield/Storm and potential southern hemisphere contingencies.

2. REQUIREMENTS AND TECHNOLOGY DATABASE

Conventional communication requirements databases are often of limited value in specific cases. By their very nature, stated communication requirements are mission dependent. When a military organization is asked to furnish general communication requirements, it must, perforce, base them on its general mission. These may or may not match the specific requirements or capabilities of an actual operation. In fact, it is likely that general requirements will exceed specific requirements, when viewed case by case.

Furthermore, it should be recalled that the User Requirements Data Base (3) was established by the Defense Communications Agency (now Defense Information System Agency (DISA)) as a planning tool for future MILSATCOM architecture studies, *not* as a tool for scenario-dependent communication capacity allocation. Thus, although the URDB, the MILSATCOM Requirements Data Base (MRDB), and other similar communication requirements databases have important archival and high-level MILSATCOM architecture planning value, their utility to the present project is limited.

The recent experience derived from Just Cause, Desert Shield, and Desert Storm is far more pertinent to the project focus on corps-level operations of a contingency nature than are conventional communication requirements databases. Fortunately, excellent raw data are available from Desert Shield/Storm. These have been analyzed by RAND and used to create realistic hypothetical scenarios, as will be discussed in a later section.

RAND devoted considerable time and effort in supporting SKW in its task of producing a requirements and technology database. These activities are detailed in Appendix A, which outlines the general data collection plan; identifies the source of the data, their function, and interaction with one another; indicates the procedure for satisfying communication requirements; and describes the structure and content of the SKW database.

The technical database accumulated by SKW will, when completed, be indispensable. It is to contain, at a requisite level of detail, the technical characteristics of all military and commercial communication satellites that can support the military operations to be analyzed. This database should include existing, planned, and proposed communication satellite types operating at frequencies from UHF, through SHF, to EHF. It must also contain, again at a requisite level of detail, the technical characteristics of all military and commercial communication satellite earth terminals capable of operating with the foregoing communication satellites. Inasmuch as earth terminals are normally regarded as comprising the amplifiers, antennas, and receivers up to the intermediate frequency (IF) interface, this

technical database must also include the associated modems and switches. (It is at this level that problems of interoperability and compatibility are often encountered.) Finally, the technical database must contain the technical characteristics of jamming systems that might be encountered.

3. SCENARIO DEVELOPMENT

OPERATIONAL EXPERIENCE

Operation Just Cause

The Panama operation in December 1984 was the first operation in which military and commercial satellites were used for both tactical and strategic communication. Because of its short duration and the existence of not only a good civilian communication infrastructure but also a substantial military communication satellite link to the Continental United States (CONUS) from SOUTHCOM (resident in Panama), the operational experience gained from Operation Just Cause is of limited qualitative value in designing hypothetical scenarios for future contingency operations. Nonetheless, it is an interesting example of a unique operation.

As noted earlier, the use of commercial communication satellite service in Operation Just Cause was unprecedented. Based in large part on the close relationship between the U.S. Army and ALASCOM in the state of Alaska, it was natural for ALASCOM to be asked to provide service early in the operation. Alaska's large size (586,400 sq mi versus 3,022,387 sq mi for CONUS), rugged terrain, harsh climate, and remote location astride the Arctic Circle pose severe communication constraints. Yet its strategic location has led to a widespread and growing military and civilian population. As a result, ALASCOM provides a diversity of communication services unparalleled elsewhere. Among other things, ALASCOM has designed and operates or maintains a secure digital private-line service for the General Services Administration, AUTOVON for DISA, ARCONET for Atlantic Richfield, the Meteor Burst Communications System for the Alaskan Air Command, the FAA/NWS Network, the Joint Surveillance System for the Alaskan Air Command, the public packet-switched network Alaskanet for general use, and Rapid Deployment Transportable Earth Stations (RDES) for the U.S. Army. It was one of the RDES that was deployed to Panama for Operation Just Cause.

ALASCOM personnel transported an RDES terminal to Panama aboard a C-141 and erected it at Quarry Hill near a U.S. Army MILSATCOM terminal used by SOUTHCOM. Because the ALASCOM satellite, Aurora I, is at 143 degrees west longitude, whereas Panama is at about 80 degrees west longitude, they were operating at the fringe of their earth-coverage antenna. To compensate for this, ALASCOM chose to use an 8-m-diameter antenna, rather than the customary 4.5-m-diameter antenna. The communication satellite

link was to provide international communication access for the Panamanian government and to tie in the military commands. The link supported (at least) one T1 circuit (1.544 Mb/s) with various channelizations using a DS-1 switch. Terrestrial circuits were used to connect the Alaskan end of the satellite link to CONUS.

Military communication satellite systems also played a prominent role in Operation Just Cause. However, their contribution to contingency operations in general is difficult to assess because Operation Just Cause was not typical of such operations in two important respects. First, CINCSOUTH, which ran the tactical mission, is resident in Panama and had an extensive and well-structured communications infrastructure in place. Second, the warfighting phase was so short that it ended before there was any significant MILSATCOM augmentation.

The existing communications that were used during the pre-attack phase consisted of 29 channels of voice and data on DSCS, 37 channels of voice and data on INTELSAT, and two T1 (1.544 Mb/s) national gateway channels on DOMSAT. When augmented to support the government rebuilding phase, the military component of the architecture included two channels on FLTSAT, 34 wideband subchannels on AFSAT, 30 channels on LEASAT, and 54 channels on DSCS. Because of restricted viewing angles, only the CONUS FLTSAT was used. For DSCS, the EastPac and WestLant satellites were used. The ground mobile forces (GMF) terminals used were TSC-85a, -93a, -85b, and -93b by the Army, and the TSC-94a and -100a by the Air Force. No jamming was encountered and no spread spectrum modems were used.

Operations Desert Shield/Storm

Desert Shield officially began on August 8, 1990, and Desert Storm began January 17, 1991. The Persian Gulf area of responsibility (AOR) was very large, about twice as large as the European theater in which U.S. forces fought in World War II. There are few population centers with associated communication infrastructure; the AOR consists mainly of desert with some mountains along the coastal areas. To provide communications over such vast inter- and intra-theater distances created a great demand for both commercial and military satellite communications. The demand for inter- and intra-theater connectivity rose very quickly and was met rapidly by a variety of space assets. Once the ground war began, satellite communications played a key role in maintaining connectivity with a rapidly moving force over vast distances.

A military communication infrastructure of either the Defense Communications System (DCS) or tactical communications was almost nonexistent in the AOR at the time of

deployment. Some limited commercial communication existed in the general area but not where the tactical forces would be deployed. Therefore, early in Operation Desert Shield, a mix of commercial, long-haul DCS, and tactical communications had to be assembled to support the buildup of forces. The majority of SHF connectivity was provided by the DSCS, but commercial T1 channel banks on two INTELSAT satellites, along with appropriate satellite terminals, were leased and placed into operation early in the deployment. INMARSAT was used to supplement the UHF SATCOM needs.

The detailed satellite communication throughput in the form of connectivity "bubble" diagrams was provided to the Defense Communications Agency (DCA) (now DISA) by USCINCCENT on an almost daily basis during Desert Shield/Storm. RAND was provided a sampling of the "bubble" diagrams [1] by Major Ochman, the DSCS GMF operations officer at DCA. He was the primary liaison officer between the network planners at the Regional Space Support Centers (RSSCs) and the technical experts at the DSCS Network Management Office (DOT). The scenarios for Desert Shield/Storm defined by the "bubble" diagrams are summarized by units in a classified companion Note. A summary of the satellite throughput by satellite is presented in Figure 1. These results are the same as those presented by DCA for DSCS throughput with the addition of the throughput defined by the "bubble" diagrams for SKYNET and the commercial INTELSAT. Various other sources have presented more INTELSAT throughput, but much of this was intelligence data not included in the "bubble" diagrams. There is some ambiguity in the amount of intelligence data throughput presented in these other sources because the data are classified. Therefore, it was decided for this Note to define the satellite communication throughput for Desert Shield/Storm as that delineated by the USCINCCENT "bubble" diagrams, which are presumed not to include intelligence data.

Prior to Desert Shield, there was only a small amount of throughput, as shown in Figure 1, on August 1, 1990. The primary satellites supporting CENTCOM in the AOR were the East Atlantic (EL) and the Indian Ocean (IO) DSCS satellites. There were three tactical terminals and one shipboard terminal providing critical command, control, communications, and intelligence to CENTCOM headquarters at MacDill AFB, Florida. The EL DSCS provided 2.3 Mb/s throughput whereas the IO DSCS provided 2.24 Mb/s, for a total of 4.54 Mb/s. A little more than a month later, the number of tactical terminals had increased from 4 to 48 and the total satellite throughput had increased to 38.27 Mb/s. At this time, the IO satellite had reached maximum capacity as configured (i.e., saturation). Additional satellite communication capacity was requested but could not be met. By reconfiguring the EL and IO DSCS antennas and channel usage, slightly more capacity was obtained. Several

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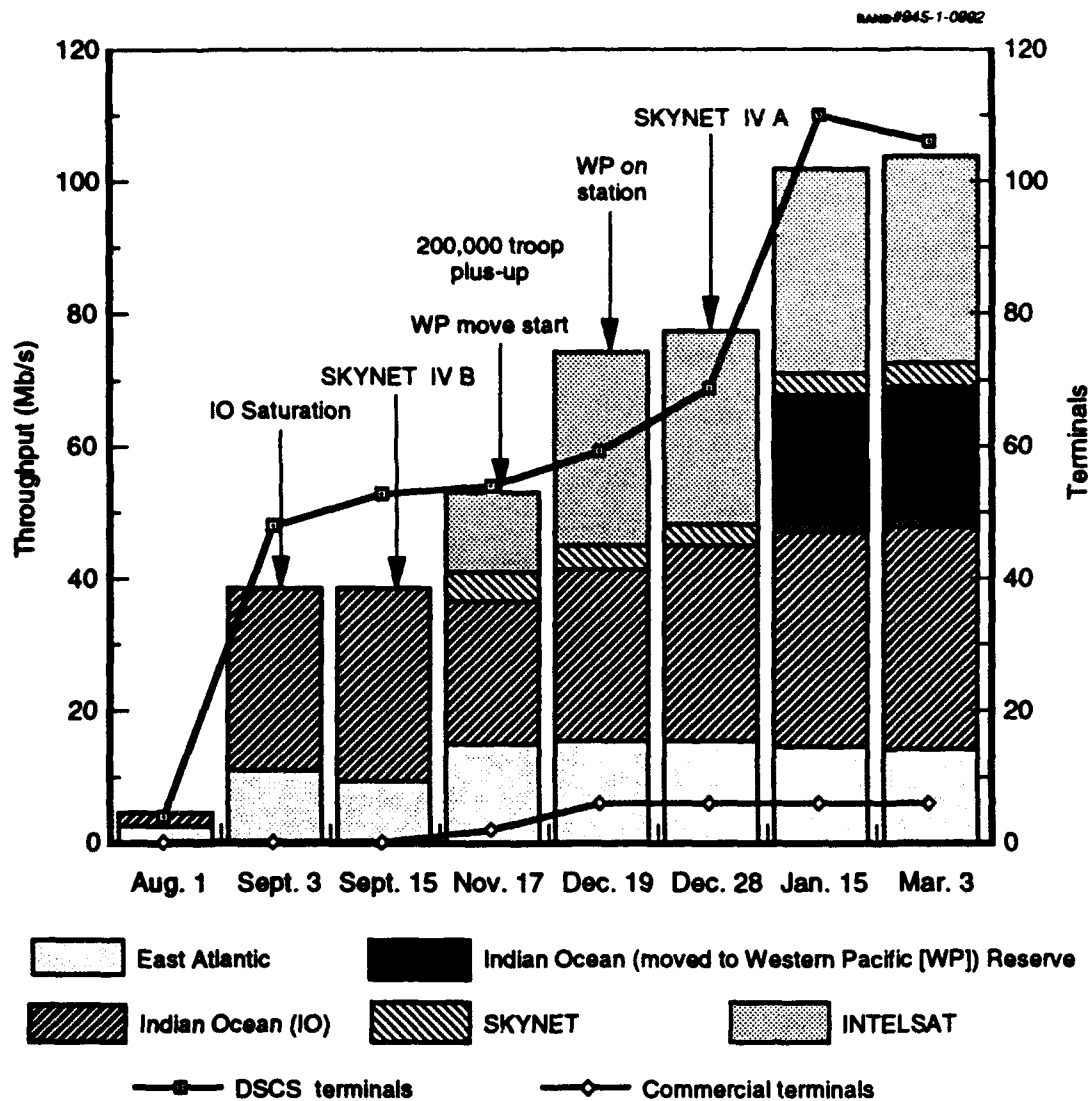
Figure 1—Buildup of CENTCOM Network

terminals were transferred from the IO satellite to the EL satellite, which better optimized the total throughput.

By September 15, 1990, the total throughput had increased slightly to 38.59 Mb/s and the number of terminals had increased from 48 to 53. In addition, the United Kingdom offered 3.5 Mb/s capacity on their SKYNET IV B satellite. The next major change occurred when the President announced a 200,000 troop plus-up. It was decided to move the reserve Western Pacific (WP) DSCS satellite to a position near the IO satellite. By November 17, 1990, the total DSCS throughput had dropped to 36.22 Mb/s, but the number of terminals

had increased to 54. The GMF networks continued to grow. There were now two commercial terminals and the INTELSAT throughput was 12.35 Mb/s.

By December 19, 1990, the WP satellite was on station but not ready for use. The total DSCS throughput had grown to 41.34 Mb/s and the number of terminals was 59. The commercial terminals had increased to six and the INTELSAT throughput was 29.24 Mb/s. Capacity on SKYNET IV A was offered but held in reserve due to the effect on the control system. By December 28, 1990, the total DSCS throughput had grown to 44.6 Mb/s supporting 69 terminals. The INTELSAT throughput remained at 29.24 Mb/s. Finally, the IO Reserve (WP) DSCS satellite was available as reflected in the total DSCS throughput of 67.65 Mb/s on January 15, 1991, supporting 110 terminals. The INTELSAT throughput increased to 30.82 Mb/s, still supporting six terminals. The DSCS performance remained the same on March 3, 1992, but the INTELSAT throughput increased slightly to 31.39 Mb/s. It should be noted that the primary DSCS throughput was for tactical requirements and that the commercial INTELSAT throughput was for long-haul communications back to CONUS. In fact, the majority of the long-haul communications was provided by INTELSAT.

CONTINGENCY OPERATIONS

As in most military operations, there are a number of functional areas associated with contingency operations. To analyze the communications requirements of the maneuver force commanders, it is convenient to categorize them accordingly: Command and Control, Maneuver, Intelligence, Combat Service Support, Combat Aviation (Air Force, Army, Navy/Marine Corps), Air Defense, Fire Support, Force Development, and All Other (which includes personnel actions, humanitarian assistance, ordnance, medical, engineer, transportation, and signals).

Contingency operations are characterized by four recognized phases:

- **Peacetime Indications and Warning.** Signs of internal unrest or impending threats of overt action during this phase will lead to initial preparatory actions.
- **Crisis Management.** When events escalate to a point where conflict appears inevitable, armed forces are brought into a suitable offensive or defensive posture during this phase.
- **Campaign Execution.** The most vigorous military activities occur during this phase, when forces are engaged in combat.

- **Reconstitution.** Battle will have been concluded (or, perhaps, degenerated into mop-up operations) during this phase. Forces are being withdrawn and civil control reinstituted as peacetime conditions are restored.

It can be appreciated that the overall intensity of activity in the various functional areas will increase from a peacetime baseline level as operations enter the peacetime indications and warning phase and pass through the crisis management phase. They will peak during the campaign execution phase and drop off during the reconstitution phase toward a (possibly) new peacetime baseline. This behavior is diagrammed qualitatively in Table 1 for each of the functional areas across the four phases of an operation. Table 1 illustrates, for example, how Command and Control and Intelligence are intensive activities during the first three phases and taper off during Reconstitution. Maneuver, on the other hand, gradually increases in level and remains intensive through Reconstitution. In any event, all of the functional areas are intensely active during campaign execution. Communication usage will generally follow the pattern of the operational activity.

OPERATIONAL SCENARIOS

Operation Just Cause was seen earlier in this section to offer little in the way of operational data on which to base exemplary scenarios for hypothetical contingency operations because of its short duration and the existence of a large peacetime baseline communications capability associated with SOUTHCOM, which is resident in Panama.

Operation Desert Shield/Storm offers much usable data because records for space communication are available for 13 time snapshots during the six-month operation. These could be used as the basis for a scenario containing an equal number of snapshots. However, it is not likely that better analytical results could be derived from examining so many snapshots in comparison with looking at, say, four, one corresponding to each of the four operational phases just described. Because of limited resources, only the snapshot corresponding to the campaign execution phase, which is the one with the greatest communications activity, was prepared for the three scenarios to be described. It is recognized, however, that much can be learned about alternative space communication techniques by considering snapshots in the other three phases of contingency operations.

To arrive at a set of scenarios representative of a wide range of contingency operations in diverse locations having topographic and climatic extremes and employing different kinds of forces, we considered the following three cases: Southwest Asia (i.e., Desert Shield/Storm), Korea, and Argentina. These scenarios, which are presented in the following sections, are

Table 1

Baseline Communications Requirements According to the Four Operational Phases and Selected Operational Functional Areas

	Operational Phase											
	Peacetime Indications and Warning			Crisis Management			Campaign Planning and Execution			Reconstitution		
	Intensity of Operations											
Operational Functional Area	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low
Command and Control		X		X			X				X	
Force Deployment and Maneuver		X		X			X			X		
Intelligence	X			X			X				X	
Combat Service Support		X			X		X				X	
Combat Aviation												
Air Force			X		X		X					X
Army			X			X	X					X
Navy/USMC			X		X		X					X
Air Defense			X			X	X					X
Fire Support			X			X	X					X
All Other			X			X	X				X	

not given in much detail. Their purpose is only to identify, size, and locate U.S. forces according to the days of the campaign after they are deployed to a region and to establish their communications requirements by geographic location and data rates. The source of the scenarios was the 1994–99 Defense Planning Guidance Scenario Set [2].

4. SOUTHWEST ASIA SCENARIO

The Southwest Asia (SWA) scenario was chosen because the Desert Storm operations provided actual communications data and requirements. In addition, the region's distance from the CONUS, as well as its geographical setting, topography, and climate, provided a highly demanding example. Since Iraq has not met all of the UN sanctions as yet, it is not unlikely that a similar campaign, in which U.S. forces would be involved, could occur. In this revisited SWA scenario, we concentrate on the campaign execution phase, when the communications requirements are the greatest.

Although jamming was not employed by Iraq, we assess its likely effects as if it had been used; jamming of space communications is likely to have important effects. It would be difficult to mount full-time major barrage jamming across all frequencies or even across just those used for the satellite communications frequencies of UHF, C-band, and X-band. Sporadic jamming against key communications for command and control during periods of U.S. plan execution might be more effective. Rather than assume all space communications frequencies might be jammed a certain percentage of time, we select transponders to be jammed. Selective jamming of these transponders, say, for about six hours per 24-hour day in 15-minute (or shorter) intervals might be effective. The Iraqis should assume that if they jam for long, continuous periods of time, their jammers will be attacked and destroyed.

Theater: Southwest Asia
Region: Saudi Arabia, Kuwait, Iraq
Year: 1997–2002

General Political Situation Leading to the Operation: The United States has agreed, under a mandate from the United Nations, to assist the Kuwaiti government regain control and maintain territorial integrity from aggression by Iraq, and to prevent or defend against invasion of Saudi Arabia.

Strategic Goal: Defend Kuwait and Saudi Arabia against Iraqi military attacks on the country's leadership, government institutions, military forces, and key installations. Protect and evacuate U.S. personnel.

U.S. Objective: Regain government control and help maintain the territorial integrity of Kuwait and Saudi Arabia and prevent the defeat of their military forces.

Operational Guidelines: U.S. forces will not initiate the use of nuclear or chemical weapons. Operations involving U.S. personnel will stringently limit U.S. casualties.

Command Levels: U.S. Army forces will operate as part of a combined command under an overall mandate of the United Nations.

Campaign Duration: Most of the combat operations during the campaign execution phase are expected to last for approximately 15 days.

Campaign Duration by Phase:

Indications and warning: 5 days

Crisis management: 20 days

Campaign planning and execution: 15 days

Restoration: 14 days

Military Force Lists:

Iraqi forces in Kuwait theater of operations

545,000 personnel (*New York Times*, 1/17/91)

Republican Guards: 8 divisions, 110,000 troops total

Other units: about 36 divisions

The numbers of Iraqi major items of equipment listed in Table 2 are approximately the same as at the beginning of ODS. Although these numbers were reduced as a result of ODS, additional quantities are being purchased or replaced through repairs. Undoubtedly, if Saddam Hussein decides to attack again, he will endeavor to begin with the same size, or larger, arsenal he had previously, so the numbers of items in Table 2 seem realistic.

Table 2

Iraqi Equipment in Kuwait Theater of Operations

Item	Maximum
Tanks	4550
Armored Personnel Carriers (APCs)	2880
Artillery	3257
Combat aircraft	600

Participating Coalition Armed Forces

Coalition total	737,000 personnel (*Washington Post*, 2/24/91) 190 ships (*New York Times*, 2/12/91) 1700 combat aircraft (*New York Times*, 2/12/91)
Air sorties	air war, 95,000; ground war, 15,000
United States: CENTCOM	532,000 personnel (*Washington Post*, 2/24/91) 2,000 tanks, 1800+ fixed wing aircraft, 120 ships
ARCENT	280,000 (*New York Times*, 2/12/91)
LOG	25,000 personnel in Logistics Command (*Washington Post*, 12/18/91) XVIII ABN Corps HQ VII Corps HQ 1st Cav Div 82nd ABN Div 24th Mech Div 101st AASLT Div 1st Inf Div 1st Armd Div 3rd Armd Div 2nd ACR 3rd ACR III Corps Arty 11th ADA 12th Avn Bde I COSCOM II COSCOM
NAVCENT	80,000 personnel (*New York Times*, 2/12/91) More than 400 fighter/bombers with six CVBGs More than 120 vessels
JTFME	Wisconsin BBBG Saratoga CVBG Midway CVBG Kennedy CVBG Ranger CV Theodore Roosevelt CV America CV Missouri BB
MARCENT	90,000 personnel (*New York Times*, 2/12/91) 1st MEF 1 Mar Div 2 Mar Div 1st Marine Air Wing 1st FSSG 4 MEB 5 MEB

CENTAF	50,000 personnel (*New York Times*, 2/12/91)
	1200 aircraft
	1st TFW (F-15)
	4th TFW (F-15)
	34th TFW (A-10)
	35th TFW (F-4G)
	37th TFW (F-117A)
	48th TFW (F-111)
	52nd TFW (F-4G)
	363rd TFW (F-16)
	401st TFW (F-16)

Operations Plans:

Enemy ground and air operations

U.S. naval, air, and ground operations

UN coalition forces consisting of Kuwait, Saudi Arabia, Egypt, Bahrain, the Emirates, Turkey, Syria, United Kingdom, France, Italy, and other allies participating in combined operations.

The Operational Setting: The scenario begins with Iraq's occupation of Kuwait and the deployment of U.S. forces in Saudi Arabia to deter further Iraqi aggression.

Prevailing Circumstances: High-intensity conflict. No nuclear, chemical, or biological weapons are employed by either side. U.S.-led coalition of multinational forces under the auspices of the United Nations.

Current Situation: Iraq invades Kuwait and Saudi Arabia with 21 divisions, 450 combat aircraft, and 2200 tanks.

The United States sends:

Army—4-2/3 divisions: 2 armored, 2 mechanized, and 2 airborne brigades

Air Force—15 fighter squadrons and 4 bomber squadrons

Naval—3 aircraft carrier battle groups, 12 Marine expeditionary forces

Other—Special Forces

Theater and Area of Operations: The theater of operations, where Air Force, Army, and Naval forces are based and operate from, includes Saudi Arabia, Kuwait, Bahrain, Qatar, and Iraq. The area of operations, where ground forces deploy, includes Saudi Arabia, Kuwait (including offshore naval units), and the southern part of Iraq. See Figure 2.

Figure 3 depicts the organizational structure of the joint and combined commands in Southwest Asia.

Mission: Assist Saudi Arabia and Kuwait resist the Iraqi invasion. Counterattack to free Kuwait and restore its political borders. Protect and evacuate U.S. citizens in the region.
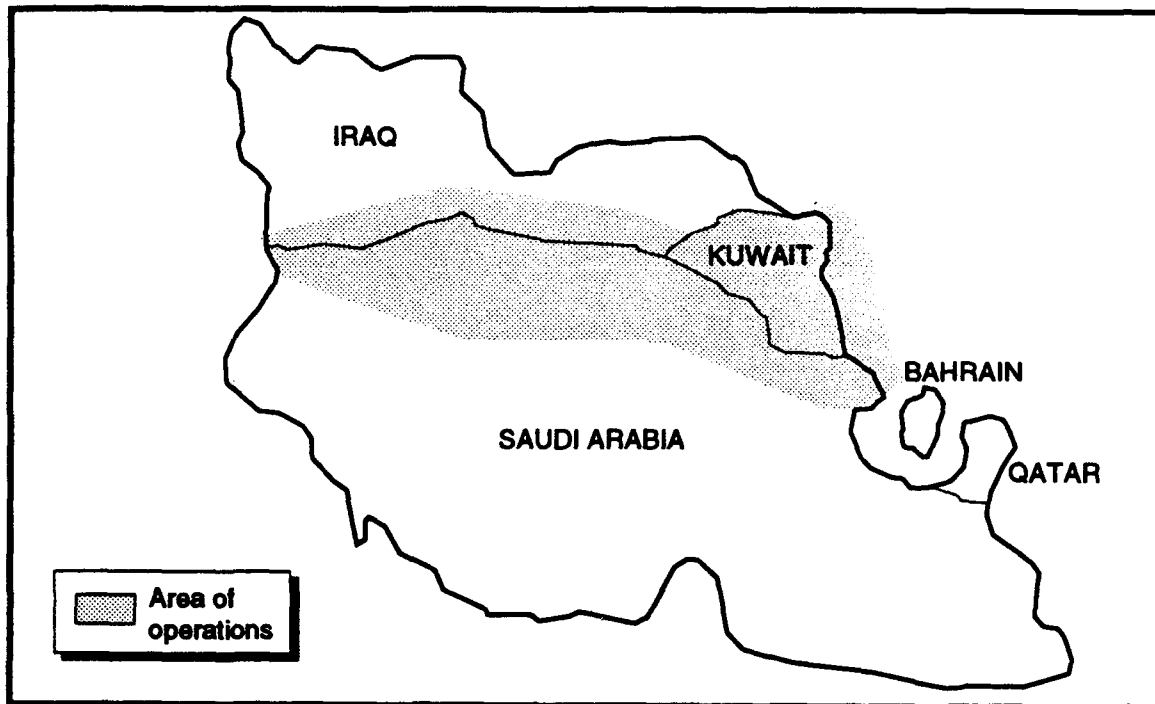
RAND#945-2-0992

Figure 2—Theater and Area of Operations
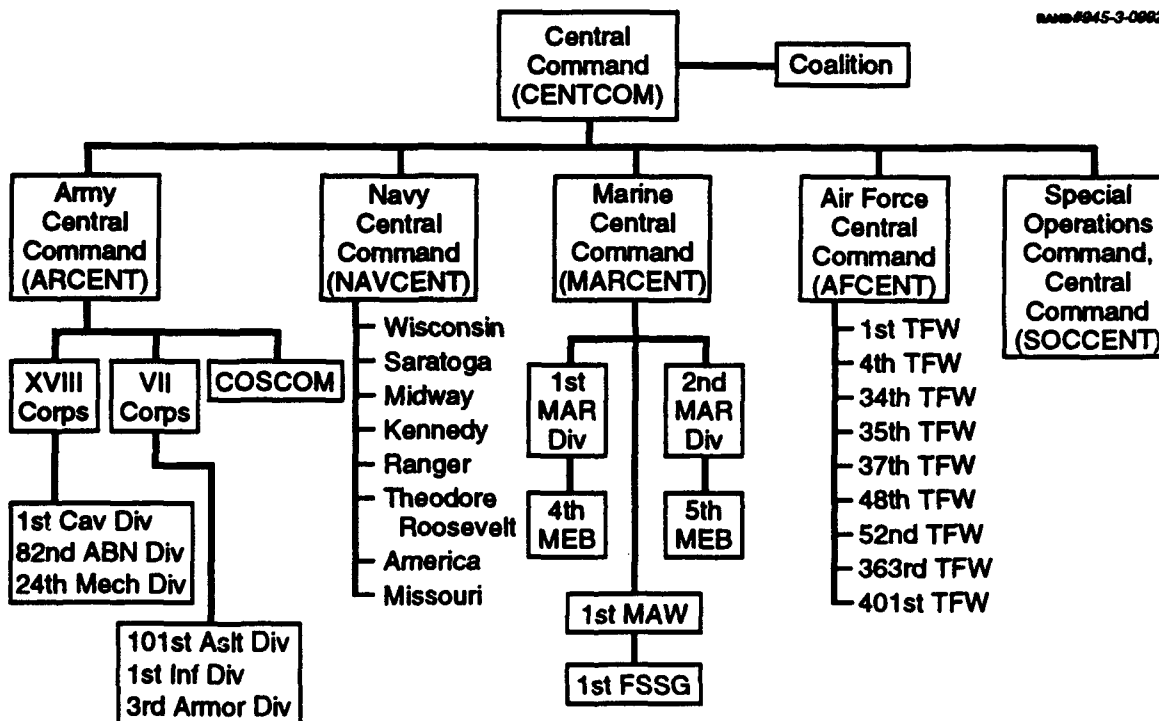
RAND#945-3-0992

Figure 3—Joint, Combined Command Structure, Southwest Asia

Communications Requirements: Table 3 lists the headquarters by geographic location and the satellite terminals and their data rates.

Table 3

Locations of Satellite Terminals, by Type, and Data Rates
(Southwest Asia Scenario)

Unit From	Terminal	Unit To	Terminal	Data Rate
CONUS Base	TSC-100A/20	CENTCOM		
"	TSC-100A/20	"	TSC-85A/20	544
"	LST-8000/8	"	TSC-85A/20	544
DCA	FSC-78/60	"	TSC-85A/20	256
"	TSC-85B/20	"	TSC-93B/20	256
"	TSC-85B/20	"	TSC-93B/20	256
CONUS Base	TSC-100A/20	"	TSC-86A/20	256
CONUS Base	TSC-93B/20	"	TSC-93B/20	256
"	TSC-100A/20	"	TSC-93B/20	256
"	TSC-100A/20	"	TSC-85A/20	544
"	TSC-100A/20	"	TSC-93B/20	256
Joint, Combined HQ	TSC-85B/20	"		
"	"	Coalition Cmd	TSC-85A/20	544
"	"	"	"	544
ARCENT	"	XVIII Corps Hq	"	544
"	"	VII Corps Hq	"	544
"	"	1st Cav Div	TSC-93B/8	256
"	"	82nd Abn Div	"	256
"	"	24th Mech Div	TSC-85A/20	256
"	"	101st AASLT Div	"	256
"	"	1st Inf Div	TSC-93B/8	256
"	"	3rd Armd Div	"	256
"	"	COSCOM	TSC-85A/20	544
NAVCENT	"	Wisconsin	"	256
"	"	Saratoga	"	256
"	"	Midway	"	256
"	"	Kennedy	"	256
"	"	Ranger	"	256
"	"	Theodore Roosevelt	"	256
"	"	America	"	256
"	"	Missouri	"	256
MARCENT	"	1st Mar Div	TSC-93B/20	256
"	"	2 Mar Div	"	256
"	"	1st MAW	"	256
"	"	1st FSSG	"	256
"	"	4 MEB	"	256
"	"	5 MEB	"	256
CENTAF	"	1st TFW	TSC-100A/20	544
"	"	4th TFW	"	544
"	"	34th TFW	"	544
"	"	35th TFW	"	544
"	"	37th TFW	"	544
"	"	48th TFW	"	544
"	"	52nd TFW	"	544
"	"	363rd TFW	"	544
"	"	401st TFW	"	544
SOCCENT	"	CENTCOM	"	544
SUPT CMD	"	"	TSC-85B/20	544
Terminals: 46			Total	17,248

NOTE: Data rate × 2 = 34,496.

5. KOREA SCENARIO

The Korea scenario was chosen because it represents a plausible case in which conflict could occur at any time. U.S. forces are already in the region and a great deal is known about North and South Korean forces; also, communications requirements and systems capabilities data are available. In addition, Korea's distance from the CONUS, its geographical setting, topography, climate, and potential for jamming represent a demanding case for communications support of military operations.

The North Koreans have tactical jammers developed by the Soviet Union and China. These jammers would be expected to be used during hostilities. It would be difficult to mount full-time major barrage jamming across all frequencies or even across just those used for the satellite communications frequencies of UHF, C-band, and X-band. Instead, sporadic jamming against key communications for command and control during periods of U.S. plan execution might be more effective. Rather than assume all space communications frequencies might be jammed a certain percentage of time, we designate transponders to be jammed. Selective jamming of these transponders, say, for about six hours per 24-hour day in 15-minute (or shorter) intervals might be effective. The North Koreans should assume that if they jam for long, continuous periods of time, their jammers will be attacked and destroyed.

> Theater: Pacific
> Region: Korea
> Year: 1997–2002

General Political Situation Leading to the Operation: The United States has agreed, under a mandate from the United Nations, to assist the South Korean government regain control and maintain territorial integrity from aggression by North Korea, and to prevent or defend against invasion of South Korea.

Strategic Goal: Defend the territorial and economic integrity of the Republic of Korea. Restore an acceptable balance of power in Northeast Asia. Help create an environment where free political and economic institutions can thrive.

U.S. Objective: Prevent the defeat of Republic of Korea (ROK) military forces. Defeat North Korean forces. Prevent any third-party country from intervening and widening the scope of the conflict. Avoid becoming involved in a major land war on the Asian continent.

Operational Guidelines: U.S. forces will not use nuclear or chemical weapons first, but will be permitted to engage in conventional combat south of the demilitarized zone (DMZ). U.S. forces will not be permitted to conduct ground offensive operations north of the DMZ unless so ordered by the President.

Military Force Lists:

North Koreans in Korean theater of operations

14 divisions, 1,040,000 personnel, all branches

Other units: approximately 10 divisions

Table 4

North Korean Equipment

Item	At the Beginning of Conflict
Tanks	3,675
APCs	1,800
Artillery	10,000
Combat aircraft	628

North Korean Navy

35,000 personnel

33 combat ships

21 submarines

Participating South Korean armed forces:

555,000 personnel, all branches

40 ships, 5 submarines, 60,000 personnel

200 combat aircraft, 40,000 personnel

2 mechanized infantry divisions

Table 5

South Korean Equipment

Item	At the Beginning of Conflict
Tanks	1,560
APCs	1,100
Artillery	2,000
Combat aircraft	400

United States
Korea Command   318,000 personnel
1500 tanks, 800 fixed wing aircraft, 100 ships

AR Korea   40,000 personnel

LOG   15,000 personnel in logistics command
XVIII ABN Corps HQ
VII Corps HQ
82nd Abn Div
24th Mech Div
1st Inf Div
3rd Armd Div
2nd ACR
3rd ACR
12th Avn Bde
COSCOM

NAV Korea   50,000 personnel
2 squadrons of fighter/bombers with five CVBGs
100 vessels

JTF Korea   80,000 personnel
Wisconsin BBBG
Saratoga CVBG
Midway CVBG
Kennedy CVBG
Theodore Roosevelt CV

MAR Korea   80,000 personnel
1st MEF
1 Mar Div
2nd Mar Div
1st Mar Air Wing
4 MEB
5 MEB

AF Korea   11,000 personnel, 16 fighter squadrons and 4 bomber
squadrons, 800 aircraft
1st TFW (F-15)
34th TFW (A-10)
35th TFW (F-4G)
37th TFW (F-117A)
48th TFW (F-111)
363rd TFW (F-16)

Theater and Area of Operations: The theater of operations, where Air Force, Army, and Naval units are based and operate from, includes all of North and South Korea, plus offshore areas. The area of operations, where ground forces deploy, extends approximately 50 miles north and south of the demilitarized zone (DMZ). See Figure 4.

Prevailing Circumstances: High-intensity conflict. No nuclear, chemical, or biological weapons are employed by either side. The only outside support is from the United States; no other country's military forces are involved.

Current Situation: North Korea attacks South Korea with three armies consisting of three armored and 15 mechanized infantry divisions and five combat air squadrons.

The United States reinforces to restore the DMZ and limit North Korean advances while extracting such heavy enemy losses that the North Korean government stops attacking and sues for peace.

U.S. forces consist of:

Army—5 divisions: 2 armored, 2 mechanized, and 1 airborne

Air Force—16 fighter squadrons and 4 bomber squadrons

Naval—5 aircraft carrier groups

1 Marine expeditionary force

Other—Special Forces

Mission: Assist South Korean forces resist the North Korean invasion. Limit enemy advances and restore the DMZ. Protect and evacuate U.S. citizens in the region.

Campaign Duration by Phase:

Indications and warning: 0 days

Crisis management: 45 days

Campaign execution: 25 days

Restoration: 21 days

Figure 5 depicts the organizational structure of the joint and combined commands in Korea.

Communications Requirements for Korea Scenario: Table 6 lists the headquarters by geographic location and the satellite terminals and their data rates.
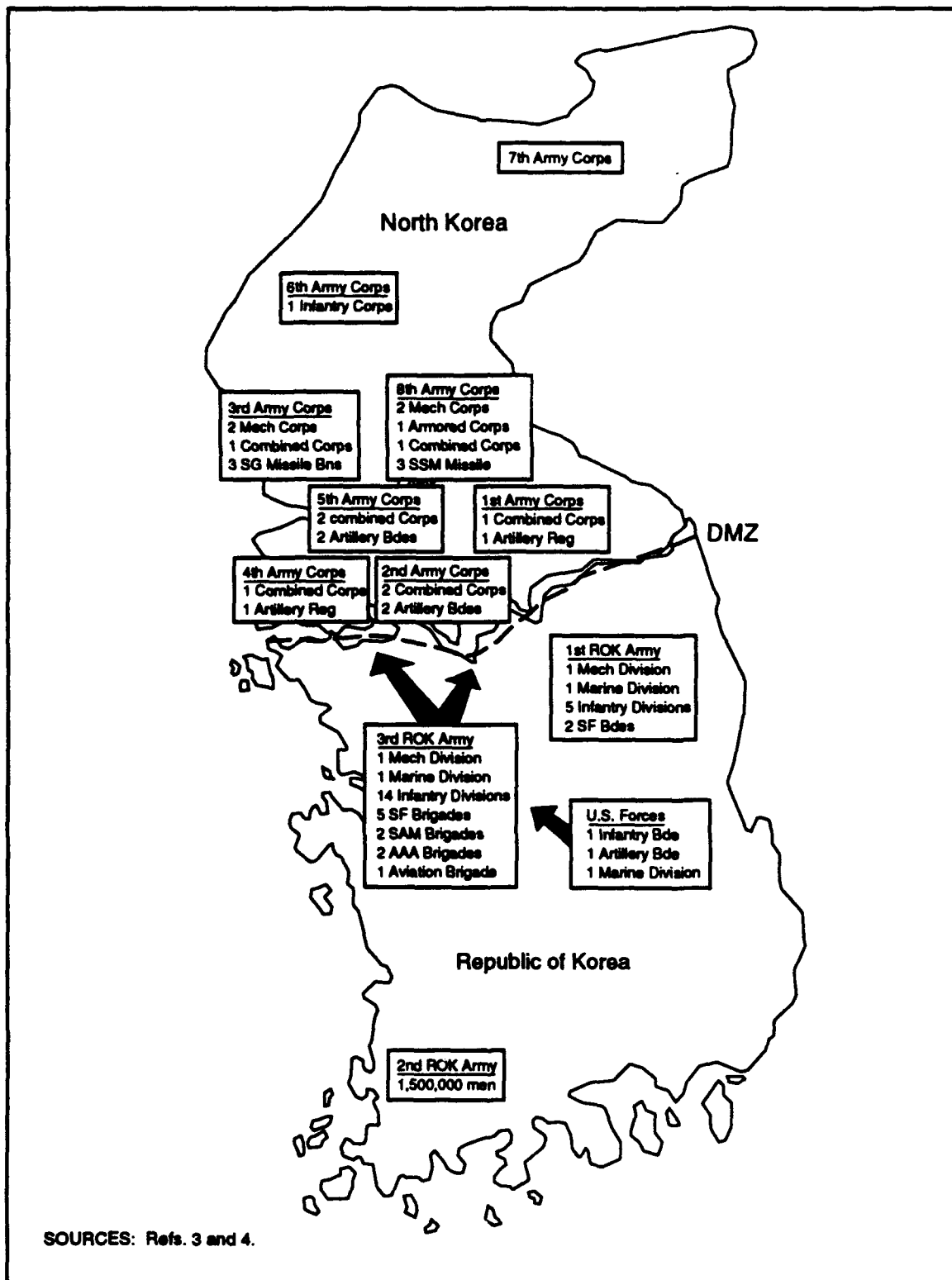
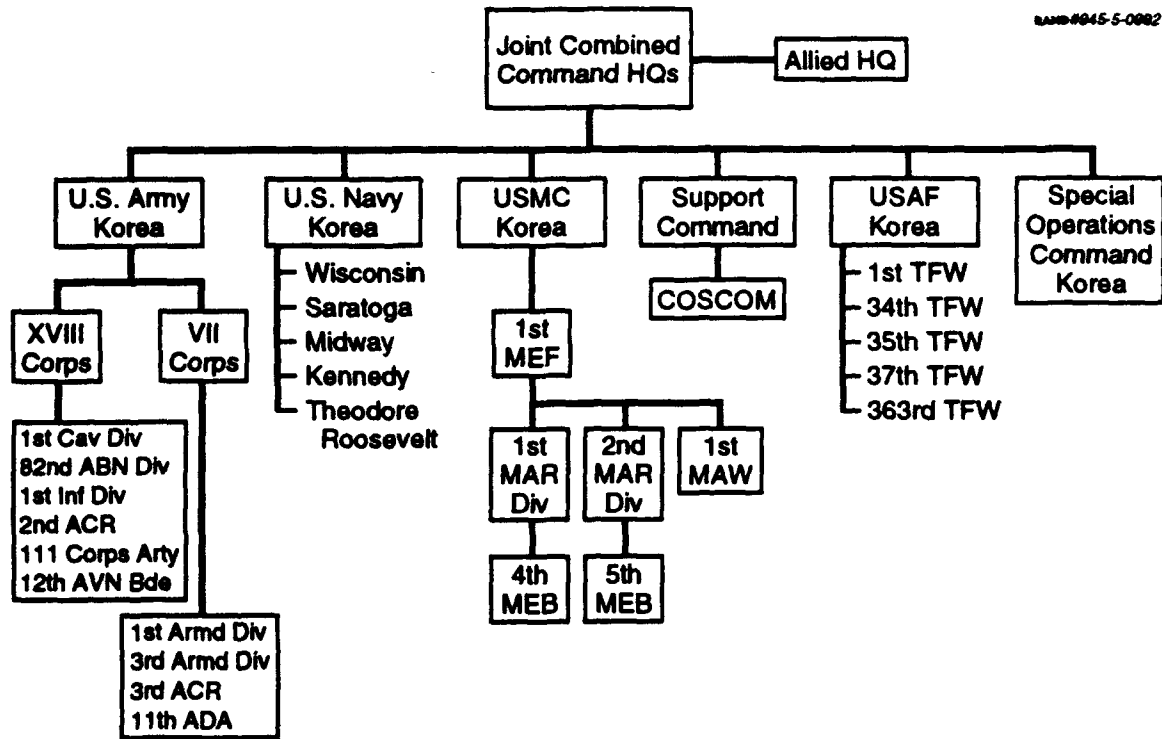**Figure 4—North and South Korean Force Deployments: Pre-D-Day**

Figure 5—Joint, Combined Command Structure, Korea

Table 6

Locations of Satellite Terminals, by Type, and Data Rates
(Korea Scenario)

Unit From	Location	Terminal	Unit To	Location	Terminal	Data Rate
CONUS Base	Ft Belvoir	TSC-100A/20	ROK-US CFC	Seoul		
"	Ft Detrick	TSC-100A/20	"		TSC-86B/20	832
"	Ft Meade	LST-8000/8	"		TSC-86B/20	256
DCA	NORTHWEST	FSC-78/60	"			268
"	Ft Buckner	TSC-85B/20	"		TSC-86B/20	256
	Landstuhl	TSC-85B/20	"		TSC-86B/20	512
CONUS Base	Diego Garcia	TSC-100A/20	"		TSC-94A/20	256
CONUS Base	MacDill AFB	TSC-93B/20	USAF, Korea		TSC-94A/20	512
"	Langley AFB	TSC-100A/20	USAF, Korea		TSC-94A/20	544
"	Andover	TSC-100A/20	USAF, Korea		TSC-94A/20	
"	Ft Bragg	TSC-100A/20	SOCOM		TSC-93B/20	128
Joint Comb. HQs	Seoul	TSC-85B/20	AR Korea		TSC-93B/20	544
"	"	"	NAV Korea	"	TSC-93B/20	544
"	"	"	MAR Korea	"	"	544
"	"	"	MAR Korea			544
"	"	"	AF Korea		"	544
"	"	"	SPT CMD		"	544
"	"	"	SOC Korea		"	544
"	"	"	SOC ROC-US CFC		"	544
AR Korea	"	"	XVIII Corps		"	288
"	"	"	VII Corps		"	288
"	"	"	NAV Korea		"	288
"	"	"	MAR Korea		"	288
"	"	"	AF Korea		"	288
"	"	"	SPT CMD		"	288
"	"	"	SOC Korea		"	288
XVIII Corps	"	"	VII Corps		"	256
"	"	"	1st Cav Div		"	256
"	"	"	82nd ABN Div		"	256
"	"	"	1st Inf Div		"	256
"	"	"	2nd ACR		"	256
"	"	"	III Corps Arty		"	256
"	"	"	12th Avn Bde		"	256
VII Corps	"	"	1st Armd Div		"	256
"	"	"	3rd Armd Div		"	256
"	"	"	3rd ACR		"	256
"	"	"	11 ADA		"	256
NAV Korea	"	TSC-85B/20	Wisconsin	Afloat	"	256
"	"	"	Saratoga	"	"	256
"	"	"	Midway	"	"	256
"	"	"	Kennedy		"	256
"	"	"	Theodore Roosevelt	"	"	256
"	"	"	MAR Korea		TSC-93B/20	288
"	"	"	SPT CMD		"	288
"	"	"	AF Korea		"	288
"	"	"	SOC Korea		"	288
MAR Korea	"	"	SPT CMD		"	288
"	"	"	AF Korea		"	288
"	"	"	SOC Korea		"	288
"	"	"	1st MEF		"	288
1st MEF	"	TSC-85A/20	1st Mar Div		"	256
"	"	"	2nd Mar Div		"	256
"	"	"	1st MAW		"	256
AF Korea	"	"	SOC Korea		"	256
"	"	"	1st TFW		"	256
"	"	"	34th TFW		"	256
"	"	"	35th TFW		"	256
"	"	"	363rd TFW		"	256
Terminals: 56					Total	18,240

NOTE: Data rate × 2 = 36,480.

6. SOUTH AMERICA SCENARIO

Argentina was selected for the South America scenario primarily because of its distance from the CONUS and its demanding location. Since Argentina lies between the 23rd and 55th parallels, south, and is situated between approximately 1,500 and 2,175 nautical miles below the equator, this region is considered to be an interesting and demanding case from the standpoint of the U.S. capability to provide satellite communications there. In the other two regions, both space and nonspace communications means exist.

Jamming will be assessed in this scenario. It would be difficult to mount full-time major barrage jamming across all frequencies or even across just those used for the satellite communications frequencies of UHF, C-band, and X-band. Instead, sporadic jamming against key communications for command and control during periods of U.S. plan execution might be more effective. Rather than assume all space communications frequencies might be jammed a certain percentage of time, we designate transponders to be jammed. Selective jamming of these transponders, say, for about six hours per 24-hour day in 15-minute (or shorter) intervals might be effective. The Argentines should assume that if they jam for long, continuous periods of time, their jammers will be attacked and destroyed.

Theater: Southern Command
Region: Argentina
Year: 1997-2002

General Political Situation: In late 1994, in the midst of an economic crisis brought on by a combination of higher oil prices, impossible debt service payments, and the end of food exports to the European Economic Community (EEC) and Russia, the democratically elected Peronist regime is overthrown by a military junta made up of officers representing the far right. To deflect criticism of their coup, these ultranationalist officers plan a series of foreign adventures both to distract the public at home and to make Argentina the dominant power in the southern hemisphere so as to position the nation to stake its claims on the huge mineral wealth of Antarctica. The ultimate goal of the Argentine junta is the conquest of the one-fourth of Antarctica the nation has historically claimed for itself. To achieve this strategic goal, the nation must become the dominant power in the southern half of South

America and in the South Atlantic so that no other nation can challenge its claims in the region.

Argentine Deployments:

Army: Although the peacetime armed force of 95,000, including an army of 45,000, is relatively small, Argentina has reserves of 250,000 men that were called to service in 1982 and is capable of putting up to six million men into arms in an emergency. The army is organized into four corps spread over five military regions. The corps contains two armored cavalry brigades, two mechanized brigades, two mountain brigades, one jungle brigade, one airborne brigade, 11 artillery brigades, one engineer regiment, and five independent brigades.

Strategic Goal: Prevent the strategic balance in the South Atlantic from being disrupted. Ensure that no territorial adjustments are made by force. Allow all nations to continue to use Antarctica for peaceful purposes.

U.S. Objective: Maintain a balance of power between Chile and Argentina so that U.S. access around Cape Horn and Antarctica is not disrupted. Ensure that the Falklands/Malvinas dispute does not generate into a war or damage relations with either Britain or the Organization of American States.

Military Force Lists:

Argentine theater of operations:

Argentine National Army and Air Force

The numbers of Argentine major items of equipment are listed in Table 7.

Table 7

**Equipment in Argentine
Theater of Operations**

Item	At the Start of Operations
Tanks	300
APCs	500
Artillery	300
Combat aircraft	150

United States

SOUTHCOM   25,000 personnel
100 tanks, 50 fixed wing aircraft, 15 ships

AR SOUTH

    LOG   1,000 personnel in logistics support command
XVIII ABN Corps HQ
Airborne infantry brigade from 82nd Abn Div
Ranger Regiment from 101st AASLT Div
Light infantry brigade from 1st Inf Div
2nd ACR - 1 squadron
11th ADA - 1 battery
12th Avn Bde - 1 battalion
COSCOM - 3 logistic support teams

NAVSOUTH   10,000 personnel

JTFSA   Kennedy CVBG - 2 aircraft carrier groups
Ranger CV - 1 amphibious brigade

MARSOUTH   15,000 personnel
1 Mar Div
1st Marine Air Wing
Amphibious task force

AFSOUTH 50th   5,500 personnel
133 aircraft
1st TFW (F-15) - one squadron
34th TFW (A-10) - one squadron
35th TFW (F-4G) - one squadron

Prevailing Circumstances: Mid- to low-intensity conflict. No nuclear, chemical, or biological weapons are employed by either side. The only outside support is from the United States; no other country's military forces are involved.

Theater and Area of Operation: The theater of operation, where Air Force, Army, and Naval forces are based and operate from, includes Argentina, Chile, and a portion of Uruguay. The area of operations (see shaded area in Figure 6) is limited to the eastern portion of Argentina and the western border of Uruguay, concentrated mainly around Buenos Aires.

Current Situation: The former Argentine government is on the verge of falling. Fighting continues by factions of the Army and the Air Force, but not the Navy, together with the national police, against the democratic and popularly supported New People's Government, whose leader appealed to the United Nations for military intervention and other assistance on behalf of the fledgling government.
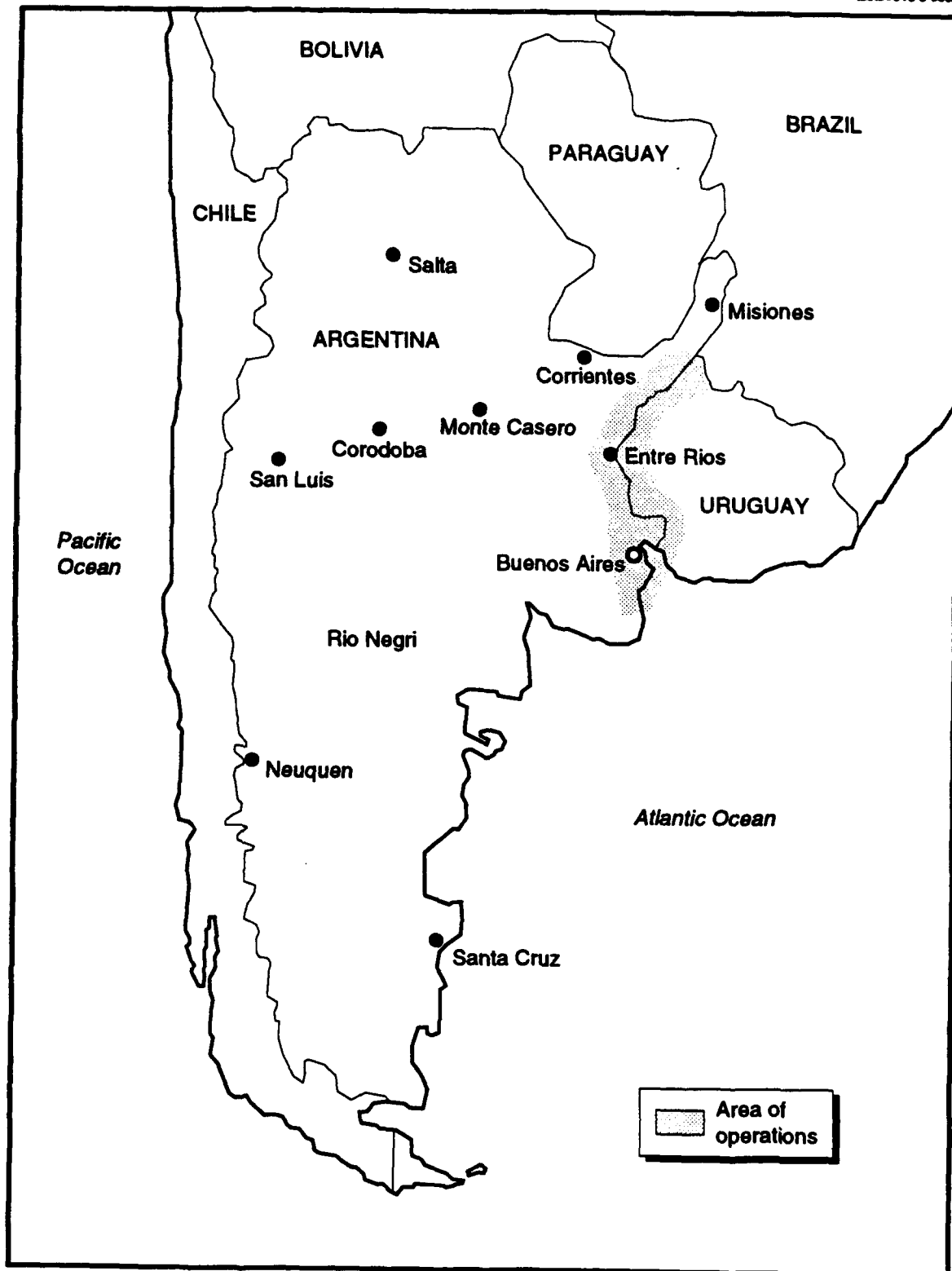
Figure 6—Map of Argentina and Chile

The United States, acting under the auspices of the United Nations, is embarked on recovering American and other hostages being held by the Argentine Army, protecting U.S. citizens in the region, evacuating them if necessary, helping to restore order, and beginning peacemaking/peacekeeping operations until a new nationally elected democratic government can gain control.

U.S. forces consist of:

Army:	1 Ranger regiment
	1 airborne infantry brigade
	1 light infantry brigade
Air Force:	1 squadron of ground attack aircraft
Naval:	2 aircraft carrier groups
	1 amphibious brigade
Other:	Special Forces

Mission: Free and evacuate U.S. hostages and other U.S. civilians who desire to leave the conflict zone; secure and protect the U.S. Embassy; quell the fighting and restore order; provide military assistance and humanitarian aid to U.S. and Argentine citizens.

Summary of Major U.S. Military Operations:

U.S. forces make three landings:

1. Airdrops by Army paratroops at airports in Buenos Aires, Punta Indio, and Garin to capture the airports for use by U.S. forces, deny Argentine Air Force military aircraft and facilities from participating in hostilities, and block military reinforcements by air from Mendoza, LaBanda, and elsewhere in Argentina.

2. Marine amphibious landing to secure the U.S. Embassy at Buenos Aires.

3. Marine amphibious assault to free American hostages at Garin.

Campaign Duration by Phase:

Indications and warning: 0 days

Campaign planning and execution: 7 days

Crisis management: 10 days

Restoration: 30 days

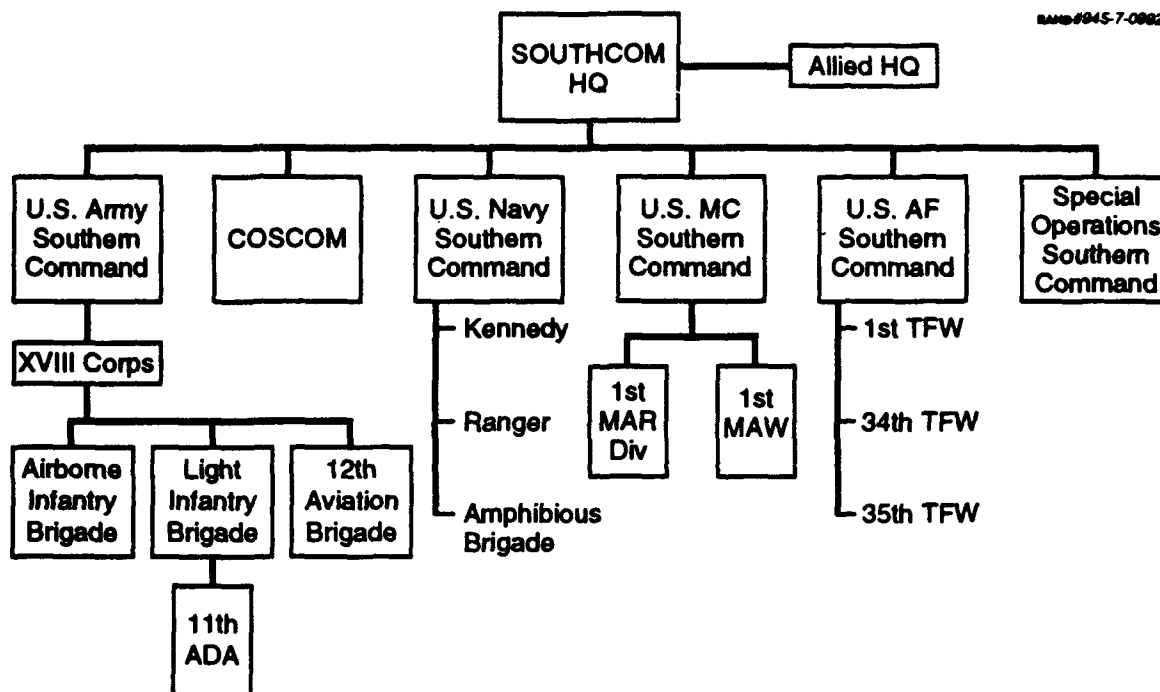Figure 7 depicts the organizational structure of the joint and allied commands for the Argentina campaign.

Figure 7—Joint, Combined Command Structure, Argentina

Communications Requirements: Table 8 lists the headquarters by geographic location and the satellite terminals and their data rates.

Table 8

Locations of Satellite Terminals, by Type, and Data Rates
(Argentina Scenario)

Unit From	Location	Terminal	Unit To	Location	Terminal	Data Rate
CONUS Base	Ft Belvoir	TSC-100A/20	SOUTHCOM HQ	Panama		
"	Ft Detrick	TSC-100A/20	SOUTHCOM HQ		· TSC-85B/20	832
"	Ft Meade	LST-8000/8	SOUTHCOM HQ		TSC-85B/20	256
DCA	NORTHWEST	FSC-78/60	SOUTHCOM HQ			268
"	Ft Buckner	TSC-85B/20	SOUTHCOM HQ		TSC-85B/20	256
"	Landstuhl	TSC-85B/20	SOUTHCOM HQ		TSC-85B/20	512
CONUS Base	Diego Garcia	TSC-100A/20	NAVY SOUTHCOM HQ		TSC-94A/20	256
CONUS Base	MacDill AFB	TSC-93B/20	USAF SOUTHCOM HQ		TSC-94A/20	512
"	Langley AFB	TSC-100A/20	USAF SOUTHCOM HQ		TSC-94A/20	544
"	Andover	TSC-100A/20	USAF SOUTHCOM HQ		TSC-94A/20	
"	Ft Bragg	TSC-100A/20	Special Operations Command		TSC-93B/20	128
SOUTHCOM HQ	Panama	TSC-85B/20	Allied HQ	Buenos Aires	TSC-93B/20	256
"	"	"	Army South	"	TSC-93B/20	288
"	"	"	NAV SOUTH	"	"	288
"	"	"	MAR SOUTH		"	288
"	"	"	AF SOUTH		"	288
"	"	"	SOC SOUTH		"	288
AR SOUTH	Buenos Aires	"	XVII Corps HQ		"	256
"	"	"	NAVSOUTH		"	288
"	"	"	MARSOUTH		"	288
"	"	"	AFSOUTH		"	288
"	"	"	SOCSOUTH		"	288
"	"	"	COSCOM		"	288
NAV SOUTH	Afloat	"	MARSOUTH		"	288
"	"	"	AFSOUTH		"	288
"	"	"	SOCSOUTH		"	288
"	"	"	COSCOM		"	288
"	"	"	Kennedy		"	256
"	"	"	Ranger		"	256
"	"	"	Amphib Bde		"	256
MAR SOUTH	"	"	1st Mar Div		"	256
"	"	"	1 MAW		"	256
AF SOUTH		"	SOCSOUTH		"	288
"	"	"	1st TFW		"	256
"	"	"	34th TFW		"	256
"	"	"	35th TFW		"	256
"	"	"	11th ADA Bde		"	256
XVIII Corps	"	TSC-86B/20	COSCOM		"	288
"	"	"	ABN Inf Bde		"	256
"	"	"	Light Inf Bde		"	256
"	"	"	12th AVN Bde		"	256
"	"	"	11th ADA Bde		"	256
Terminals: 40					Total	12,012

NOTE: Data rate × 2 = 24,024.

7. COMMUNICATION NETWORK SIMULATION

Prior to the termination of the TEXTRON effort, RAND met with TEXTRON to study their simulation (SIMAN), which was to serve as the basis for the desired communications network simulation. (Because it is still a suitable basis from which to proceed, it is described in detail in Appendix B.) However, it is unlikely that a simple communication network simulation will suffice. What is needed is a system configuration tool capable of configuring a satellite communication system using the specified equipment and communication requirements within the spatial and temporal relationships laid out in the scenarios to be analyzed. The ability of a computer simulation to assess accurately the adequacy of the communication support to a given scenario is directly related to its ability to reflect realistically the extremely complex nature of a large communication system. Communication engineers often tend to think in terms of link analyses in which they can embed the fairly straightforward effects of power budgets, antenna gains, link margins, etc. Even jamming can be introduced and assessed relatively simply. This is not the case on the system or network level where links can no longer be viewed individually. The ripple effect of changing channel allocations or coping with natural or man-made outages is generally calculable only by careful analysis.

There are a number of simulations available at the link and system level. Among these is the Network Assessment Model (NAM), which was developed for the Signal Center of the U.S. Army at Fort Gordon. A brief demonstration to representatives from RAND in December 1989 suggested that the NAM is strongly oriented toward terrestrial rather than space communications. The NAM was demonstrated at TEXTRON and the source code was delivered to them in August 1991.

Another network-level MILSATCOM simulation is under development at the Aerospace Corporation. An in-progress demonstration was given to representatives from RAND and USARSPACECOM in September 1991. This simulation incorporates the URDB and it is planned that other databases will be included as they become available. When completed, it will model the existing and planned MILSATCOM satellites, including MILSTAR.

The Aerospace Corporation has developed another computer simulation called COMNET that makes link calculations between commercial earth terminals and communication satellites. It also gives coverage diagrams and sets up networks. COMNET was demonstrated at the same time as the MILSATCOM simulation referred to above and a

version has been given to RAND for experimentation. (The COMNET simulation is described in Appendix B.)

These and other space communication simulations will be important components in the system configuration tool needed to exercise and analyze the scenarios generated in the present research. To achieve this end, it will be necessary to augment and integrate them to make the result as flexible and user-friendly as possible.

When the system configuration tool is completed, the analytical procedure will be to configure the terrestrial segment specified in the scenario and the communication network necessary to satisfy the stated communication requirements using the MILSATCOM space assets that are available at that time. If necessary, or desired, commercial earth terminals and communication satellites can be included. If shortfalls still exist, satellites may be relocated in orbit, as was done in Desert Shield/Storm, or conceptual augmentation satellites can be introduced.

If the scenario calls for jamming, jamming source and nature must be specified to determine suitable countermeasures. Jammers in-country or otherwise at risk can be destroyed or, if only troublesome rather than disruptive, can be countered by employing anti-jam (AJ) techniques on those satellites and terminals that are so equipped. Jamming from a sanctuary, particularly if intense, can be countered only by anti-jam techniques. In either case, the network communication capacity will be reduced, perhaps drastically. Commercial systems, with no effective jam resistance, can be completely negated. However, it may not be in a country's best interest to jam, say, INTELSAT, if the country is using the system for its *own* communications and that of its allies. Most earth terminals, even military ones, have little jam resistance and may become significantly degraded. Recourse to advanced design earth terminals and communication satellites may then prove essential.

It can be seen that the use of the system configuration tool in its interaction with the scenario must be an iterative one in which the analyst must play a vigorous role. Only then can the utility of tactical satellites be convincingly demonstrated.

8. JAMMING

Jamming appears to be a pivotal issue. In the absence of jamming, both MILSATCOM and commercial communication satellite systems can provide communication support to large numbers of terminals distributed over large geographic areas (the combined total in ODS/S grew to over 100 Mb/s from over 100 terminals).

In terms of user types, FLTSATCOM, the UHF component of MILSATCOM, already serves small users, as does INMARSAT, the L-band component of commercial systems. DSCS, the X-band component of MILSATCOM, and INTELSAT, the C-band and K$_u$-band component of commercial systems, were originally designed to serve small numbers of large users. Although that remains an important function for them, both are increasingly serving a large number of small users.

Unfortunately, except for some developmental portable X-band modems intended for use with DSCS terminals, most military and all commercial terminals have little or no jam resistance. Although the DSCS III satellites have nulling antennas, which provide some jam resistance, the spot beams on other military or commercial satellites provide no protection against in-theater jammers. Except for a few AJ modems (e.g., USC-28) that can be used with DSCS, and then only by users with large terminals, there will be little effective jamming protection for small users until the MILSTAR system is fielded.

Jamming is not a simple matter. Large, and therefore vulnerable, jammer terminals are required—perhaps in large numbers—to jam all or most of the many transponders on several military and commercial satellites that may support tactical operations. Nonetheless, if jamming is successful, it can result in reduced communication support to tactical operations. A jammed commercial communication satellite transponder can be considered effectively eliminated, as would be an unprotected MILSATCOM transponder if jammed. For those MILSATCOM transponders or terminals that can be protected, jamming can force data-rate reductions of from 10 to 20 dB (i.e., by factors from 10 to 100) or more.

If jamming is to be regarded as a serious threat, as RAND believes it should, jam-resistant communication satellites and portable tactical jam-resistant earth terminals must be developed and fielded. The developmental X-band terminals alluded to above are a start toward improving the utility of DSCS in a jamming environment. The MILSTAR satellites and their associated terminals will help. What is not known, and can only be determined by extensive testing and analysis, is the potential for tactical satellites of special design using,

perhaps, the MILSTAR AJ waveform and operating in conventional or unique orbits and constellations. This remains a topic for future research.

9. CONCLUSIONS

The project overview in Section 1 describes how the proposed research was intended to be conducted. Briefly, SKW, RAND, and TEXTRON were to participate in a three-element program to study tactical satellite communications requirements and develop a computer-based simulation. SKW was to develop a relational database containing communications requirements and operational experience as well as technical characteristics of military and commercial communication satellites and earth terminals, whereas TEXTRON was to develop the computer simulation. RAND's role was to support SKW and TEXTRON in their efforts, formulate scenarios to use in the computer simulation, and perform analyses using the computer simulation.

The SKW effort was largely successful but incomplete. RAND developed data collection plans and assisted SKW staff by accompanying them on their initial visits to data sources to provide introduction and guidance. Lack of adequate funding prevented SKW from completing their task, but the basis for a satisfactory product has been established and the database is suitable for straightforward expansion, if desired.

RAND analyzed the communication satellite experience gathered during Operation Desert Shield/Storm (ODS/S) in considerable detail. These data were used as a communications requirement data base to design three scenarios of tactical contingency operations. The first is set in Southwest Asia and is essentially a revisit of ODS/S but with jamming. The second scenario is set in Korea to typify a large operation between in-place forces, again with jamming. The third scenario is set in Argentina to typify a small operation in a remote relocation.

Initial meetings with TEXTRON staff established that their computer simulation was adequate but would require extensive augmentation to accommodate the analysis of tactical military and commercial communication satellite systems and networks. Although TEXTRON's effort was terminated early in the study, RAND pursued the question of the system configuration tool, which is the extensive analytical element needed to complement the TEXTRON (or similar) simulation. Two such tools, COMNET and the MILSATCOM Simulator, both developed by Aerospace, typify the sorts of elements that are required.

No qualitative analyses of the RAND scenarios could be conducted without the TEXTRON computer simulation. Consequently, we make only general qualitative observations, based in part on the ODS/S experience and in part on RAND's experience with military communication satellite systems.

If jamming is to be regarded as a serious threat, as RAND believes it should, jam-resistant communication satellites and portable tactical jam-resistant earth terminals must continue to be developed and fielded. The developmental X-band terminals alluded to in Section 8 are a start toward improving the utility of DSCS in a jamming environment. The MILSTAR satellites and their associated terminals will contribute greatly. What is not known, and can only be determined by extensive testing and analysis, is the potential for tactical satellites of special design using, perhaps, the MILSTAR AJ waveform and operating in conventional or unique orbits and constellations. This remains a topic for future research.

Appendix A
DATABASE DEVELOPMENT

There were two objectives for developing the satellite communication requirements and capabilities database (SCRCDB). The first objective was to provide a set of requirements and capabilities to drive the Tactical Satellite Orbital Simulation and Requirements Study (TOSARS) simulation being developed. In this database, the user requirements would be derived from the operational experience in Operation Desert Shield/Storm (ODS/S). The second objective was to provide a much larger database for a comprehensive satellite communications planning and engineering tool. In the larger database, the user requirements from several other databases, such as the Integrated SATCOM Data Base (ISDB) [derived from the User Requirements Data Base (URDB)], the MILSATCOM Requirements Data Base (MRDB), and the MILSTAR Master Data Base (MMDB) would be included. The MMDB is expected to be contained in the MRDB. Only about 20 percent of the Army requirements are in these databases; therefore, additional effort is needed to develop the Army requirements from Army Signal Center/Training and Doctrine Command (TRADOC) requirements documents and from the CINC's OPLAN.

Data from operational experience as described in Section 3 are important sources for both the communication requirements and the capabilities parts of the SCRCDB. Operation Desert Shield/Storm is especially valuable because it is recent and very well documented in terms of actual satellite communication usage. RAND had made ODS/S "lessons-learned" studies, so there was the possibility that data gathered for those studies would apply to the TOSARS databases. RAND's responsibility was to help SKW obtain data for several databases supporting the TOSARS project. During the ODS/S data-gathering interviews, points of contact were made that were expected to carry over for additional information for TOSARS.

In early November 1991, a data collection plan was discussed at RAND. First, it was necessary to identify all military and commercial communication satellites that were used in ODS/S. Technical characteristics of these communication satellites were to be collected for two databases: (1) an archival collection to be used later for various USSPACECOM-specified purposes and (2) a subset of the larger archival collection to be used specifically for the TOSARS simulation development. For the second (subset) database, the technical characteristics and usage during ODS/S were to be gathered for military communication satellites (DSCS, FLTSATCOM, LEASAT, MACSAT, SKYNET, and others such as

GAPFILLER, LES-9, etc.) and for commercial communication satellites (INTELSAT and INMARSAT). In addition, the technical characteristics of the military and commercial terminals used in ODS/S were to be gathered and input to the database. These technical characteristics were to be detailed enough to allow link budget calculations. Some attributes necessary to describe unique characteristics are the terminal-satellite interface constraints (i.e., whether the terminal matched specifically to a particular communication satellite) and its transportability constraints. For the TOSARS modeling of tactical satellites (TACSATs), technical characteristics such as Lightweight Tactical Army SATCOM System (LTASS) and interfacing terminals such as STIX (see Acronyms) were to be established and input into the database.

ODS/S lessons-learned studies contained communication usage data; the military sources were CENTCOM, DECCO, and DISA; the commercial source was COMSAT. Terminals and usage were to be mapped to specific Army units, perhaps by using TOE and MTOE (see Acronyms) data for representative corps elements. Potential sources for the TOSARS data required were DISA, DECCO, Information Systems Command, CENTCOM, and COMSAT. Usage and location data are needed to feed the scenario simulation, so entries must be specified carefully (e.g., time span of communication activity: for Desert Shield, perhaps weekly, and for Desert Storm, daily as appropriate).

DATA GATHERING FOR THE DATABASE

RAND had established good working relationships with potential data providers in May 1991 as a result of ODS/S interviews during the Gulf War. In November 1991, these ODS/S contacts were approached by phone and letter and all agreed to help with the TOSARS data-gathering effort.

In calls and letters to these data providers, the project objective was described as development of a planning tool for assessing communications capabilities in contingencies. This tool was characterized as a simulation model looking at end-to-end communications support. Data providers were asked for a mapping between satellite usage (both military and commercial) and specific service units in ODS/S.

At the time of the interviews, we were using as a basis for the simulation model and planning tool (see Appendix B) a PC-based model called COMNET developed by the Aerospace Corporation. This model computes link budgets for commercial systems. The Aerospace COMNET model is being incrementally developed for the Air Force Space Division/XR. The current version offers transponder allocation options. The model database includes all CONUS ground entry points. The TOSARS team was given short briefings on

this model during its development, but ongoing COMNET improvements are not being folded into the USARSPACECOM work. Aerospace was extending the model to include a military counterpart, so part of the data-gathering task was to obtain link budget computation elements for each military satellite involved in ODS/S. Also, we asked data providers for data on terminals deployed with U.S. troops: technical characteristics, numbers deployed, performance indicators, and instances where commercial off-the-shelf devices might have been substituted.

We also asked data providers for any electronic databases that might have been assembled to capture ODS/S communications information, or information on who could locate and obtain such data. The intent was to run the model with the known scenarios and once it produced consistent and credible results, we would introduce jamming and repeat the experiment. The plan was also to explore how TACSATs might be used to augment the existing combination of military and commercial satellite communications under some hypothetical scenarios.

We were interested in the insight of data providers regarding requirements that were *not* filled. In the anecdotal reports, people cite "communication shortfalls," but these might simply result from unresolvable contention for resources at a given moment. We suspected it was often a prioritization problem within the services, a local misallocation, a host nation contracting issue, or some other institutional or operational explanation rather than an actual capacity shortfall. The model was intended to test these hypotheses.

Giving data providers a clear understanding of what was being requested allowed them to prepare for personal interviews in December 1991. RAND and SKW representatives attended these meetings together to coordinate the details of the data gathering. RAND saw to it that personal introductions were made between SKW and data providers at DISA, DECCO, and the J6 office for each category of TOSARS data required.

In previous interviews with DISA during ODS/S, RAND was given detailed information based on DISA's critical role in coordinating satellite access for DSCS in the Gulf theater. These data were called "bubble" diagrams, since network connectivity is pictured as connected ovals with channel capacity and other details recorded on an almost daily basis during ODS/S [1]. There was an initial surge for C^2 and C^3 requirements, largely because of CINC demands that were purposely excessive to maintain a reserve capacity, especially in voice circuits.[1] Communications usage had been rehearsed in the Golden Pheasant exercise in Southwest Asia four months before the invasion of Kuwait by Iraq.

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[1] This overbuilt voice approach was also used in Panama during Operation Just Cause.

For the TOSARS work, DISA agreed to provide a magnetic tape of daily records showing network configurations during ODS/S.[2] The data on that tape were to be sent electronically from Landstuhl to the USSPACECOM data facility at Falcon AFB. Coordination of the data transfer was entrusted to SKW through the DISA data provider, but it was not transferred before SKW had expended its resources. This data transfer will be necessary for any further expansion of the database.

DISA also provided considerable information on military terminals including technical characteristics such as antennas, bandwidth, power, physical size, and so forth. RAND made it clear that data required to generate link budget calculations for the TOSARS model was essential, and DISA agreed to provide those data as well as operational factors such as network management and augmentation using commercial elements. Individuals at Information Systems Command were suggested as additional points of contact for details on operational issues and workarounds as well as their view of trunks versus long lines. They were said to be able to provide details on the Computer-Assisted Requisition System (CARS) used in the logistics pipeline. SKW was prepared to establish this contact through DISA, if necessary, to prepare the TOSARS database.

DISA uses measures of effectiveness based on a dropout standard commonly called a "P-grade." For example, a P-10 grade means that 10 out of 1000 calls are likely to be blocked. DISA set the level of service in ODS/S to be P-10 to P-15. A P-10 grade was maintained after problems with assigned Mobile Subscriber Equipment (MSE) area codes were solved. Although DISA recognized that INTELSAT terminals were used extensively in ODS/S, precise information on the assorted military and civilian operators was said to be nearly impossible to track. However, numbers and locations of terminals and connectivity are reflected in the "bubble" charts and on the magnetic tape. Questions on SKYNET were answered by the British SKYNET liaison to DISA, and by general information on satellite positioning and usage and on interface with GMF terminals. The liaison offered to provide further details at the formal request of USARSPACECOM. SKW coordinated that request.

Information on combined STIX terminals (C, X, and K_u-band) built by California Microwave was provided by Aerospace Corporation in the course of discussions on commercial SATCOM interconnectivity (CSI) terminals used in National Security/Emergency Preparedness (NS/EP) procedures. STS, Inc., a subsidiary of California Microwave, has developed an X-band special applications terminal with a 1.2–2 m dish. Technical

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[2]There were 50 major network configuration changes during ODS/S. Whenever a mission changes, a portion of the network must be altered to support that mission and ensure interface with the satellites involved. There were 19 networks supporting 19 distinct missions. The networks were purposely overbuilt in voice, in order to take care of FAX and e-mail requirements.

characteristics of these terminals were made available to the TOSARS team. Also discussed were the LES-9, FLTSATCOM, the DARPA lightsat "MACSAT" (used by the U.S. Marines), INTELSAT, and INMARSAT. Aerospace agreed to provide additional details needed for the TOSARS project on request.

Both technical and policy issues regarding third-country jamming were discussed. Aerospace brought out issues relating to contractor participation. For the most part, contractors were extremely cooperative in ODS/S, but there were circumstances in which some simply walked off the site. This is understandable, since at the time of the walkout they were providing morale-related services (such as calls home), *not* combat support, when SCUD missiles were incoming and they were in imminent danger.

At J6Z, it was learned that the staff works directly with system managers at DISA for military satellite communications, and with DECCO, the PTTs (Post, Telegraph, Telephones), and Telecommunications for commercial satellite communications. They also deal with U.S. Military Regional Space Support Centers for GMF terminals. The J6Z office coordinates MILSATCOM requirements worldwide and solves deconfliction problems. During ODS/S, requirements were passed through DISA before they went to USARSPACECOM. Many "requirements" were not validated by the CINC. The USCENTCOM J6 handled all communications arrangements in theater, and began buying commercial satellite communications in mid-October. The J6Z contacts agreed to provide inputs to the TOSARS project on formal request through USSPACECOM, and SKW sent that request.

Several overlapping studies are looking at the role of lightsats and the role of commercial satellite communications. The MILSATCOM office is trying to restructure the architecture, proposing that no heroic survivability features be built into MILSTAR and encouraging augmentation using commercial satellite communications where appropriate.

For most of the world, however, there is little or no K_u-band coverage, so this particular type of commercial satellite communications does not have tactical support application. Domestic INTELSATS use different terminals than do international users.[3] For large footprints on the earth from the satellite (i.e., wide-area coverage), correspondingly large dishes on the ground terminals are needed to make up for the spreading loss. The *type* of service required (telephony versus switched service) is important since telephony satellites are currently full. Required tactical support must match availability of service.

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[3]IBS terminals are used by U.S. operators.

Another important issue is connectivity. Antennas for INTELSAT are communication satellite-specific. Two points may lie within INTELSAT's worldwide coverage but cannot talk to each other because each is pointing to a different communication satellite. Use of INTELSAT must be carefully considered and is not always "the answer."

Prioritization of requirements is a contentious issue, especially during a crisis situation. The J6Z manager examines validated requirements monthly (i.e., validated by the supported CINC). He assigns a URDB number and priority numbers based on expected usage. He also recommends other means than MILSATCOM, as appropriate. Judgment is based on cost, availability, contention with other requirements, time to implement the service, weather, and so forth. His office has the authority to preempt users. In ODS, USCINCCENT (GEN Schwarzkopf) was the designated supported CINC and all other CINCs had to defer to his priorities. All supporting CINCs had to get their requirements validated by CINCCENT (using a satellite access). The six people in the J6Z Contingency Support Division at the Pentagon are each assigned a CINC.

The J6Z office generously shared data on satellites, terminals, usage, and network management issues with the TOSARS team. They also discussed plans for control and standardization of the automation and management information systems involved in MILSATCOM. VADM Richard Macke, Director of J6, OJCS, is overseeing development of a revised MILSATCOM architecture that will optimize channel assignments and allocations. There are currently not enough UHF channels. At the end of 1991, the URDB was replaced by the ISDB (Integrated SATCOM Database) using Dbase IV, and SAIC was identified as the contractor helping to implement the system of about 1000 networks.

At DECCO, the TOSARS team was told by the International Communications Manager that commercial satellite communication is too costly, partly because the services go directly to the commercial owners/operators instead of working through DECCO. Commercial service was not cheap in ODS/S, but DECCO presented cost tradeoff information showing that lower costs could be realized by requesting satellite communications services through the designated channels. DECCO asserted that in Operation Just Cause (OJC), communications service demands were 150 percent of available capacity but were satisfied through automated network management and bundled lease agreements. For example, ALASCOM owed the Army 30 days on leased service after OJC, so of the 40 days the Army used the terminals in ODS, 30 were already paid for. DECCO handled the leasing in T1 increments (see Acronyms) and arranged terminal leases as well.

DECCO puts a user's request out on the DISA Acquisition Bulletin Board System (DABBS) in the form of an Inquiry Quote Order (IQO) to U.S. International Carriers. Many

military and civilian carriers and agencies are on the DABBS. There are about 25 carriers on the bidder list, and about 12 actively bid. Foreign competition is increasing. Japan had a single carrier 18 months ago, and today has three. The United Kingdom has two carriers. The IQO is approximately like a Request for Proposal (RFP). If there is an emergency, a mini-RFP with condensed boilerplate will be FAXed out. Carriers interface with COMSAT, and DECCO then interfaces with the carriers. The carriers are responsible for making all arrangements to ensure end-to-end service. They exercise circuits regularly and re-home damaged circuits.

Each of the services has its own telecommunications contracting office (TCO). USARCO is the Army's agency, funding the Army's requests through Fort Huachuca. Once requirements are identified, the TCO presents its request to DECCO in the form of a detailed specification. A Program Designator Code is assigned that identifies the organization responsible for reimbursing DECCO for the purchased service. Often the request neglects to take into account the CONUS tail of the service, and this must be factored into the contract. Other issues are whether the requested service is essential or emergency in character (which involves prioritization, turnaround time, preemption, etc.), requires mobile phone links, requires additional foreign interface, and so forth.

A Telecommunications Service Request (TSR) indicates the service time expected. Setup time depends on many factors: how clearly the requirements are specified, legalities to be overcome, complexity of the network, ease of dealing with the PTT on the other end, adding a T1 versus setting up from scratch, and number of carriers involved (e.g., AT&T may team with ALASCOM).[4]

DECCO checks all aspects of the bids and negotiates the best deal possible (not always the lowest bidder). Lease versus buy is always considered. They also check the credibility of the carrier and ability to provide the service. DECCO representatives explained the steps for obtaining a specific terminal through DECCO's equipment branch for terminal acquisition. The user then has the terminal commissioned through the FCC. DECCO will point the user to the correct service-specific TCO. For the Army, this is USARCO at Fort Huachuca. The TCO will advise on preparing the TSR. Requestors must go through an approval cycle within their appropriate service organization (Army, Air Force, etc.). They

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[4]Wide Area Telephone Service (WATS) was activated to SWA within minutes because the service was anticipated at the time of the contract. When the TSR was received, it was just a matter of flipping a switch. This took place under the Telecommunications Service Priority (TSP) system for NS/EP. There is an effort under way to lease three backbone systems to augment local PTTs in Hawaii, Puerto Rico, and Wake Island. These systems support T1 to T3 service and will be the primary interface to U.S. long-haul satellite communications in those areas.

must show need and indicate that funding is available. If approved by the TCO, the TSR is then sent to DECCO where the Telecommunications Management and Services Office (TMSO) (part of DISA, not DECCO) converts it to a TSO and routes it to the International Office (RPCI). In the case of, say, INMARSAT, the RPCI staff already has a contract in place with COMSAT for INMARSAT usage.

DECCO/RPCI then issues a delivery order describing all the terms and conditions applicable for use of the terminal. DECCO also leases terminals for Very Small Aperture Terminal (VSAT) networks. Most of DECCO's work is point-to-point and deals with bandwidth (transponder space). Even COMSAT has approached DECCO for transponder leasing.

The DECCO division chief offered to brief the TOSARS team on several new procedures and programs, on request from USARSPACECOM or USSPACECOM, and to supply any required data to help the project with either the database population task or operational elements of the proposed scenarios.

DATABASE STATUS

SKW delivered a final report and the SCRCDB diskette on January 24, 1992 [5]. Although the database was not totally populated because of limited time and money, a number of potentially useful database attributes were completed. The SCRCDB was developed using the PARADOX relational DBMS; hence, the relationships between files are established for each query.

The database has two logical portions: "requirements" and "capabilities." The requirements files are: (1) requirements source, (2) MRDB requirements, (3) recent operations requirements, (4) non-MRDB Army requirements, and (5) circuit requirements. The requirements source file contains such information as the CINC and the CINC component that developed the requirement and the type of requirement. The recent operations requirements file is designed to contain ODS/S data from the "bubble" charts [1] and the data that represent the scenarios described in Sections 3–6. SKW partially populated this file; but, since the bubble charts were hard to read, there are some discrepancies between the data in the file and those provided in the classified companion Note. These discrepancies need to be corrected.

The non-MRDB Army requirements file is designed to contain Army requirements such as those reflected in high-level Army Signal Center and TRADOC requirements documents. As noted earlier, only 20 percent of the Army requirements are in the MRDB. The circuit requirements file is designed to contain information such as connectivity, data

type (i.e., data, voice, etc.), anti-jam, low probability of intercept (LPI), scintillation protection, bit error rate, and circuit duration.

Of these requirements files, only the recent operations requirements file is even partially populated; the others are not populated at all. Inasmuch as the data that were already entered into the database had to be entered manually, it was hoped that the information for the requirements portion existed in electronic form and could simply be read into the database.

The "capabilities" portion of the database consists of two parts: the satellite capabilities and the earth terminal capabilities. The satellite capabilities files include: (1) satellite systems, (2) geostationary satellites, (3) elliptical-orbit satellites (including low-earth orbit), (4) military geostationary orbit (GEO) receivers, (5) commercial GEO receivers, (6) elliptical-orbit satellite receivers, (7) military GEO transmitters, (8) military GEO antennas, (9) commercial GEO transmitters, (10) commercial GEO antennas, (11) elliptical-orbit satellite transmitters, and (12) elliptical satellite antennas. The earth terminal capabilities files include: (1) earth terminals and (2) terminal locations.

The satellite systems file contains the name of the satellite system, its type (military, experimental, commercial, etc.), security classification, orbit type (GEO, LEO, etc.), and the number of satellites in the constellation. The geostationary and elliptical-orbit satellites files contain information to establish their location as a function of time. The terminal location file is self-explanatory except that it can be updated as a function of time by the scenario timeline script. The remaining files provide the detailed communication parameters to perform link budget calculations to determine if a given satellite system can support the communications requirements of the various terminals in a network. Satellite antenna coverage is divided into three categories: narrow coverage is chosen as 5 degrees or less, area coverage as 5 to 17 degrees, and earth coverage as greater than 17 degrees. The data from some sources did not allow an accurate estimation of antenna coverage and these fields must be better defined.

The elliptical-orbit satellites, the elliptical-orbit satellite antennas, the earth terminals, and the terminal locations files are only partially populated. The remaining capabilities files are populated to the extent that some simulation demonstration is possible. The commercial satellite capabilities came from the Aerospace COMNET databases and the parameters are different from those used for military satellites. It would be desirable to convert the commercial satellite parameters to those used by military satellite systems. The capabilities of the Lightweight Tactical Army SATCOM System (LTASS), the Defense Advanced Research Projects Agency (DARPA) UHF Lightsat, Microsat, and other TACSAT

programs need to be included in the database. These capabilities can be derived from the specifications for those programs. Also, as the database population is continued, some fields will need to be better defined.

Appendix B
SIMULATION DEVELOPMENT

The objective of the simulation development was to create an analysis and planning tool capable of assessing accurately the adequacy of the communications support in a given scenario. For example, the tool could demonstrate the effect of the deployment of lightsats on the unfulfilled tactical communication requirements in each scenario.

EXISTING SIMULATION CAPABILITY

TEXTRON had a simulation capability, SIMAN (System for Interactive Multispectral Analysis), that appeared to be a reasonable starting point for the planning tool. SIMAN, currently in version 1.3.3, is a well-developed application, written in C, that runs on Silicon Graphics workstations under the Unix operating system. SIMAN's internal databases are built on the Empress relational database system, a commercial product that must be installed on the workstation. SIMAN was developed under government contract; executable binaries are available at no charge from TEXTRON. Source code is under tighter control; TEXTRON will not release it directly, but, with justification, it can be obtained from the contract officer.

SIMAN—cumulatively about a 24–person-year effort—was originally developed to aid Space Command's Space Object Identification/Mission Payload Assessment (SOI/MPA) mission. The software helps determine the mission and status of satellites by displaying data gathered from visible light and infrared (IR) sensors in a way that allows a user to quickly understand the data and extract useful information from them.

The initial assessment of SIMAN's applicability and usefulness was that it is useful well beyond its original intent. In particular, it appeared appropriate for communication satellite constellation and link analysis.

SIMAN is an integrated, modular, extensible, interactive system. Current modules are MODEL, IMAGE, SIGSIM, ANALYZE, and ASTRO. Modules, or applications, are developed using the OMEGA (Object-oriented Methodology and Environment for Graphic Analysis) software environment. OMEGA provides a standard programming environment and a consistent user interface; it implements the operating environment for SIMAN (including pull-down menus, windowing, graphs, dialog boxes, controls, macros, scripting, and other common functions). The overall look and feel is Macintosh-like, and highly interactive.

For the purposes of communications analysis, SIMAN is perhaps best viewed as an astrodynamics and geometry engine. The relevant module is called ASTRO.

ASTRO provides visual tools for describing and simulating the astrodynamic environment. It comprises two- and three-dimensional representations of the earth, a mathematical model of the solar system including the Sun, Moon, planets, and star background, an on-line Space Surveillance Center element set catalog, and state vector and element set propagation algorithms. (The current propagator is SGP-4, identical to the propagator used at Cheyenne Mountain.) ASTRO allows the user to visually and interactively simulate the space environment at any date and time and view the interaction of orbiting bodies. It also allows the analyst to look from any stationary or moving position to any other position that may also be moving, and to track the intervisibility and distances between objects. ASTRO can accommodate restricted fields of view (representing, for example, antenna patterns), and will properly handle terrain obstructions described by Defense Mapping Agency (DMA) digital terrain data.

ASTRO calculates geometry from first principles, and sometimes produces results that are surprising at first glance. For example, a satellite with a symmetric hexagonal conic section antenna pattern directed at nadir (under consideration as a possible Iridium pattern) would be expected to produce a hexagonal footprint on a flat earth. ASTRO correctly shows that the actual footprint on the (nonflat) earth is a "hexagon with bowed-in sides."

Part of ASTRO is a "Mission Planner" that makes it easy to enter relevant information about a particular (hypothetical) satellite or constellation. (Current real space objects are already in SIMAN's baseline database.) It is then a simple matter to have ASTRO simulate the behavior of the satellite or constellation. Various windows show evolving views in three dimensions, as well as ground tracks, intervisibility, antenna coverage, and entry/exit of satellites into the fields of view of ground stations. Data windows list numerical values of selected parameters. Terrain data can be shown visually from any viewpoint. Entire simulations, or parts thereof, can be recorded for later playback and analysis.

A particular strength of ASTRO (and SIMAN) is the ease of data entry and modification. The keyboard is seldom needed. Most numerical values can be selected and entered with a sliding control (scroll-bar) moved by the mouse pointer. Visual two- and three-dimensional views are manipulated the same way, with immediate feedback. The keyboard is necessary only to set very precise numerical values. Coupled with the graphic speed and photo-realistic rendering of the Silicon Graphics workstation, this interactive ease results in an experience akin to that of a real-time flight simulator.

A shortcoming, acknowledged by TEXTRON, is SIMAN's virtually nonexistent capability for file-based output. At present, if numerical output is desired for off-line analysis, a "screen dump" to a printer is performed, a page at a time. According to TEXTRON, a file output module for SIMAN could be written relatively easily, but has not been a priority need thus far.

SIMAN's other modules are MODEL, IMAGE, SIGSIM, and ANALYZE. MODEL allows the user to create and manipulate three-dimensional models of physical objects such as satellites. The models are complete physical descriptions including sizes and shapes of structural components, heat generation, storage and dissipation parameters, solar panel rotation algorithms, material composition, and surface characteristics. This module has the look and feel of a CAD/CAM system.

IMAGE provides visible and IR imagery analysis functions, including video frame grabbing and digitization, image processing and enhancement, model overlays, image animation, and vector cueing.

SIGSIM (Signature Simulator) uses a three-dimensional model to simulate the output of sensors when viewing objects under varying geometries. A signature, for the purposes of this model, is the set of intensity-vs.-time values observed during the passage of the object through the sensor's field of view. SIGSIM is IR/visible-oriented; it does not analyze radar cross section.

ANALYZE allows a user to graphically compare how a particular orbital parameter changes with respect to some other parameter over a period of time. ANALYZE includes a database query generator that provides a point-and-click interface for a user to construct subsets of space objects that SIMAN knows about.

SIMAN's modules are highly integrated. For example, a satellite's structural details, developed in the MODEL module, are available to the ASTRO module, so that a high-magnification view of the satellite in one of ASTRO's three-dimensional windows shows the correct motion, shape, aspect, and illumination.

To provide the communication connectivity for each scenario, USARSPACECOM and the Signal Center of the U.S. Army at Fort Gordon agreed to use NAM (Network Analysis Model). NAM is strongly oriented toward terrestrial, rather than space, communications. Thus, by interfacing NAM into the TEXTRON planning tool, the Signal Center would have space communications capability added to the NAM. The value added to the resulting planning tool would be the validity of Army requirements as established by the Signal Center.

NAM, which runs on Silicon Graphics workstations, is a large, complex model with a unique and not-too-transparent user interface. As an example of how units are connected into a network using NAM to provide terrain path analysis for communications, one can pick a spot on the ground, drag a line out from it, and move the line around with the mouse. As this is done, a window shows the terrain profile under the line and the first Fresnel zone. There is concern that the NAM is a very low-level detailed tool that is not generally compatible with the TEXTRON simulation and will complicate the development and usefulness of the resulting planning tool. As mentioned earlier, SIMAN does not have a capability for file-based output. This capability will need to be added to interface between SIMAN and NAM, which are largely incompatible. Shared data files may be the only practical interface medium.

To use the SCRCDB technical characteristics data in dynamic simulations, link budget models are needed. Aerospace has developed a COMNET ("Commercial Network Exploration Tool") model for commercial satellite communications and a MILSATCOM simulator, currently containing only MILSTAR, that include link budget calculations. These might be valuable and the detailed characteristics were investigated. The MILSATCOM simulator was still in early development when demonstrated to RAND and USARSPACECOM and was not available for detailed review.

COMNET is a MS-DOS–based communications analysis program written by Richard Lucas with help from James K. Young and Russ Raymond. The project, an effort of Aerospace's Concept Development Department, was funded by the National Communications System. COMNET was developed "for NCS use in identifying potential NS/EP communication assets."

COMNET is essentially a simple radio frequency (RF) link equation calculator and commercial satellite/earth station database. Given a choice of earth stations, COMNET indicates all mutually visible communications satellites (that it knows about), allows the user to select one or more satellites, and calculates link margins as well as other communications parameters. Selected satellites and ground areas can be displayed on a colorful Mercator world map, but this is a frill; the results of value are tabulated in clearly annotated textual displays that can be printed in hard copy (although no facility is provided to save this information to a file).

COMNET makes few demands of its host computer. The executable and all its databases fit comfortably on a 720K floppy disk. COMNET can be run directly from the floppy, but works faster if run from a hard disk. The program seems to require no more than a regular IBM PC/AT-compatible with a color graphics adaptor (CGA) display. Except for

speed and monochrome vs. color display differences, COMNET worked identically on all platforms tried.

When COMNET starts up, it presents a textual splash screen with author and version information, and it proceeds to initialize itself by loading satellite, earth station, and visibility data. Depending on the CPU, this can take several minutes. The databases with the version tested contained some 275 ground areas (states, provinces, countries) and 138 satellites. The databases appear to be simple ASCII text files; thus it should be easy for the user to extend COMNET by modifying or adding to these files.

With completion of initialization, COMNET presents the main menu of 16 commands. Virtually all user action choices start here. The commands are:

1	Edit communication parameters for earth stations
2	Edit transponder loading
3	Calculate link margins and link budgets
4	Investigate satellites for possible "double-hop" link
5	List possible link satellites
6	Show map of possible link satellites
7	List visible satellites
8	Show map of visible satellites
9	List visible ground areas
A	Show map of visible ground areas
B	List all ground areas
C	List satellites and communications parameters
D	List CINCs
E	List continents and regions
F	Show map of the earth
Q	Quit

The menu is split into four areas. The first is for setting up a link and calculating link budgets. The second area is for listing or showing satellites visible to a particular ground area; the third is the converse of the second. The last area is for displaying COMNET's databases. When COMNET initializes, it preloads the data for a Washington, DC-to-Saudi Arabia link; thus, for example, the user can immediately select item 3 to see the list of mutually visible satellites and associated link margins for these areas, and can proceed to pick a satellite and obtain a detailed link budget.

Selection of item 1 in the main menu elicits a data entry screen for earth station parameters, e.g., frequency band (C, K_u), antenna diameter, data rate, and noise temperature. The user can choose earth stations from those in COMNET's database, or he can enter his own locations in terms of latitude and longitude. The user can also simply enter a ground area, e.g., Colorado, for a terminal; COMNET will then automatically enter the latitude/longitude of the center of the chosen ground area.

Menu item 2 presents a transponder loading screen, from which the available transponder bandwidth (typically 36 MHz for commercial satellites) can be split into the desired number of channels. The parameters under user control are carriers per transponder and uplink/downlink transponder loading for each ground terminal.

Menu item 3 is the gateway to the primary calculations of COMNET. Upon selection of this item, COMNET checks for possible (closed) links using mutually visible satellites, and displays a list sorted by link margin. Required earth station power is displayed as well. At this point, the user can select any satellite that closes a link and can obtain a detailed link budget. Before calculating the budget, however, COMNET queries the user for more precise values of power received at the ground terminals, if available. Lacking such input from the user, COMNET assumes a default value specific to the particular satellite. COMNET displays link budgets for both sides of the link; all relevant assumptions and parameters are listed. This information, which can be printed in hard copy, is a comprehensive summary of COMNET's inputs and results for a particular satellite and communicating earth stations.

Uplink information calculated or reproduced here includes:

> Earth station power per carrier (dBW)
> Earth station antenna transmit gain (dBI)
> Earth station EIRP required (dBW)
> Path spreading loss ($4*\pi*L^2$) (dB m^2)
> Carrier flux density at satellite (dBW/m^2)
> Satellite receiver G/T (dB/K)
> Free space loss ($4*\pi/\lambda^2$) (dB/m^2)
> Carrier-to-noise density ratio (dB/Hz)
> Noise bandwidth (dB/Hz)
> Uplink thermal carrier-to-noise ratio (dB)

Downlink information provided is:

> Satellite saturation EIRP (dBW)
> Output backoff per carrier (dB)
> Satellite EIRP used (dBW)

Total path loss (($4*\pi*L/\lambda)^2$) (dB)

Earth station G/T (dB/K)

Boltzmann's constant (dBW/K-Hz)

Carrier-to-noise density ratio (dB/Hz)

Noise bandwidth (dB/Hz)

Downlink thermal carrier-to-noise ratio (dB)

Additional information provided (with some repetition)
includes:

Total link margin (dB)

Earth station power (dBW)

Earth antenna G/T (dB/K)

The summary concludes with a list of the input parameters and information taken from the satellite database. The assumed minimum bit energy-to-noise ratio E_b/N_o, hard-wired into the code, is 7.0 dB.

Item 4 in the main menu initiates a check for possible double-hop links, using the ground areas selected earlier, and allows the user to choose the intermediate site. Items 5 and 6 list/show all satellites known to COMNET that are mutually visible by both ground areas selected earlier. Items 7 through A list/show visibility of satellites to a ground area, or vice versa. Items B through F list/show contents of COMNET's primary databases. Item Q leaves the program and returns the user to DOS.

The core of COMNET is the link budget calculation routine. Called calcmargin, it is written in C (but shows its origins in BASIC), and takes as inputs a long list of parameters read—outside the routine—from the appropriate databases. The routine is simple geometry (mostly to determine path length) and bookkeeping to tally gains and losses. The link calculations are straightforward. The input high-power amplifier backoff is calculated as the saturation input backoff, scaled by the ratio of carriers used to total carriers available. That is, in dB, total uplink backoff = saturation input backoff – N total carriers + M carriers used. Downlink (output) backoff is calculated in a similar fashion. The link equations are easily derived from first principles or can be found in standard texts and references, such as Wilbur L. Pritchard and Joseph A. Sciulli, *Satellite Communication Systems Engineering*, Prentice-Hall, 1986. Indeed, these are the calculations that communications engineers have traditionally and routinely performed by hand; COMNET has simply given them a convenient interface and appropriate databases to draw upon.

The ubiquity of the link equations in communications engineering, as well as their simplicity and ease of derivation, suggest that it makes little sense to attempt to "adapt," "excerpt," or "modify" COMNET's basic link code for use elsewhere. Although COMNET's code might serve as a guide for a simple C function, and in fact could be adopted virtually intact, it would probably be quicker and less error-prone to simply write appropriate link code from scratch, as needed for a particular application. If interference and other effects that COMNET ignores are to be accounted for, the recommendation to work from first principles acquires a stronger basis. Further, link code written from scratch, following modern software engineering principles, could probably be made more economical, extensible, and transparently reusable than COMNET's code. The COMNET databases, while simple enough, would be somewhat harder to replicate. As mentioned earlier, it would be easy to augment the databases with additional satellite and ground information, for example, military satellite data, or to cross-check or even replace data wholesale with information of known accuracy.

None of the foregoing is intended to be critical of the COMNET link code or to suggest that the program should not be "ported" to other platforms (indeed, a native Macintosh port that would exploit that machine's excellent graphic capabilities would be tempting). The COMNET code performs its intended tasks, and the program works as it was designed. It is a convenient, easy-to-use tool, readily extensible via augmentation of the databases.

SIMULATION STATUS

TEXTRON proposed an ambitious plan to upgrade the SIMAN ASTRO module of OMEGA to add satellite communication capability and to interface, at least through file sharing, with NAM. The communication capability would be modeled after COMNET. The TEXTRON personnel did not have the prerequisite satellite communication knowledge, so RAND was to help create the necessary algorithms to establish the adequacy of the satellite communication assets to meet the tactical communications requirements.

At the kickoff meeting, 4 September 1991, RAND recommended that the whole set of validated requirements (MRDB, URDB, NAM) not be used for the demonstration, but, instead, that the unvalidated requirements of the last two conflicts be modeled. In this approach, RAND would develop scenarios that would include the required military and commercial satellite communications. Using a timeline script of the communication requirements developed from the scenarios, the simulation would use the SCRCDB technical characteristics data to demonstrate dynamically the adequacy of the current satellite communication assets to meet these requirements as a function of time. By adding lightsat

space assets, the improvement in meeting the communications requirements could be demonstrated. For reasons other than the demonstration, USARSPACECOM felt that it was necessary to include the MRDB and the URDB in the SCRCDB and that NAM needed to be interfaced with SIMAN. However, RAND would develop the scenarios for contingency operations analysis.

A number of events happened to thwart the development of the simulation. First, TEXTRON had too many other obligations to meet, so the TOSARS milestones began to slip. After some of the key personnel for the SIMAN upgrade left TEXTRON, USARSPACECOM terminated the TEXTRON contract.

Appendix C
GENERAL CHARACTERISTICS OF DSCS TERMINALS

Defense Satellite Communications System (DSCS) II and III are Super High Frequency (SHF) wideband satellites. The following terminals can be used for communications through the DSCS satellites.

AN/TSC-85B is capable of multiplexing up to eight digital transmission groups (DTGs) into one super group. It then modulates the super group into one carrier frequency, which is then transmitted to a satellite for frequency translation and subsequent retransmission down to another AN/TSC-85B or AN/TSC-93B terminal.

AN/TSC-93B is a smaller terminal that can break down two DTGs of the super groups. Each DTG has a 576 kb/s transmission rate. At a voice-channel rate of 16 kb/s, each terminal is capable of handling 288 voice channels. Because of the constraint on bandwidth, many digital group inputs were limited to 256 and 288 kb/s during ODS.

AN/TSC-94A Non-Nodal Terminal is used for point-to-point SHF tactical satellite communications. It can operate in a point-to-point configuration with another AN/TSC-94A terminal or as a spoke in a hub-spoke configuration with an AN/TSC-100A Nodal-Mesh terminal. The terminal is capable of providing full duplex communication over a satellite using single transmit and receive carriers. It is equipped with an 8-ft diameter antenna but can be operated using the 20-ft-diameter antenna. The maximum data rate that can be transmitted or received is 1688 kb/s.

AN/TSC-100A Nodal Mesh Terminal is a full-duplex multicarrier communication terminal capable of operating over two satellites simultaneously. The terminal can transmit carriers in the 7.9 to 8.4 GHz range and simultaneously receive carriers in the 7.25 to 7.75 GHz range. It can be operated using an 8-ft diameter or a 20-ft diameter antenna or both. The communication capability depends on the type of modems used. The maximum data rate achievable is 4632 kb/s.

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